NUTRIENT TIMING
for
Optimal Performance and Training Adaptation

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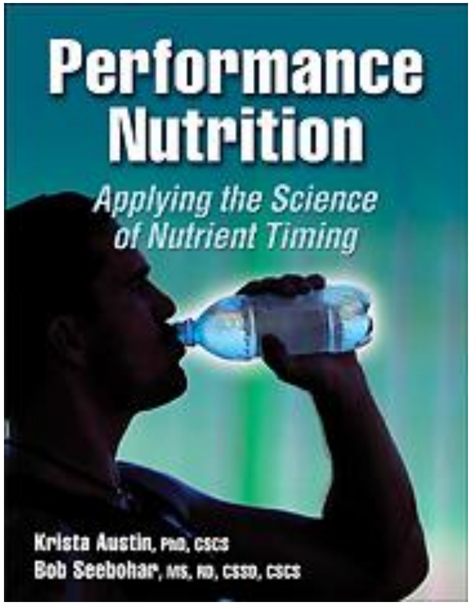
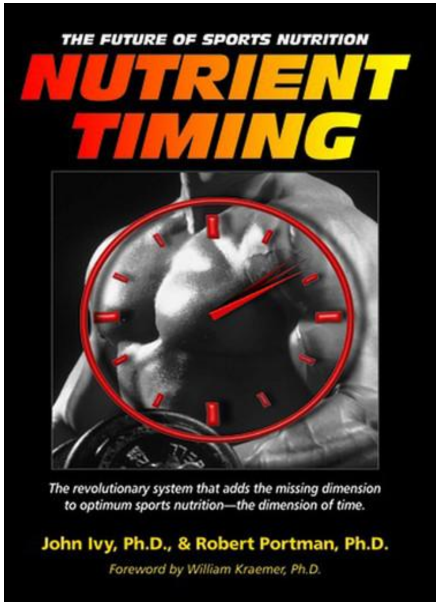
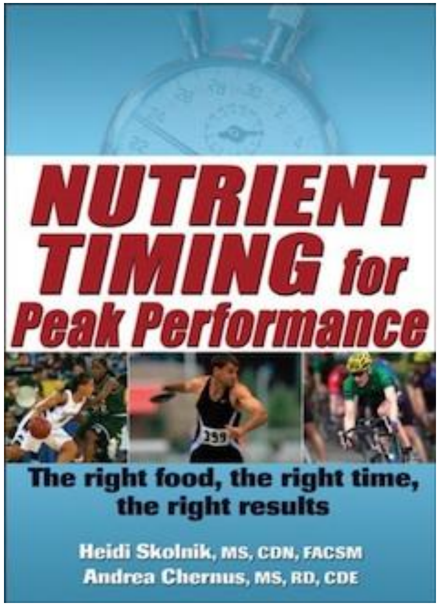
Chief Science Officer
DYMATIZE Nutrition
Dallas TX

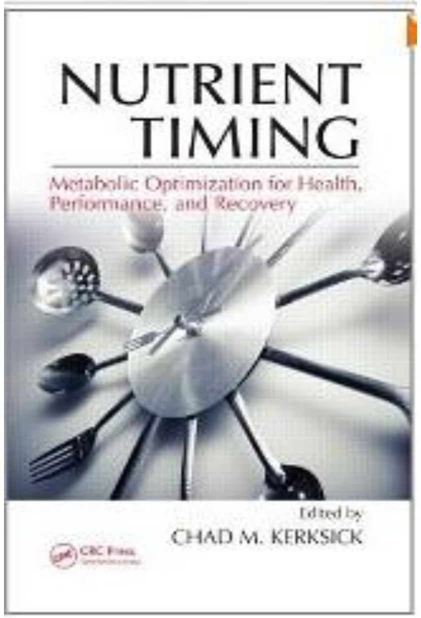
SPORTS
EUROPA
PRODUCTS

Nutrient Timing
START THE PRESSES!


Performance Nutrition
Applying the Science of Nutrient Timing
Krista Austin, PhD, CSCS
Bob Seebohar, MS, RD, CSSD, CSCS


THE FUTURE OF SPORTS NUTRITION
NUTRIENT TIMING
The revolutionary system that adds the missing dimension to optimum sports nutrition—the dimension of time.
John Ivy, Ph.D., & Robert Portman, Ph.D.
Foreword by William Kraemer, Ph.D.


NUTRIENT TIMING for Peak Performance
The right food, the right time, the right results
Heidi Skolnik, MS, CDN, FACSM
Andrea Chernus, MS, RD, CDE


NUTRIENT TIMING
Metabolic Optimization for Health, Performance, and Recovery
Edited by
CHAD M. KERKSICK
CRC Press

Nutrient Timing

Nutritional strategy in which precise amounts of nutrients are delivered at precise time points, relative to exercise, in order to enhance performance or training effects.

What does Nutrient Timing Mean?

- Nutrition before Training &Competition
- Nutrition during Training & Competition
- Nutrition immediately/shortly after exercise

One Day = 24 hours!

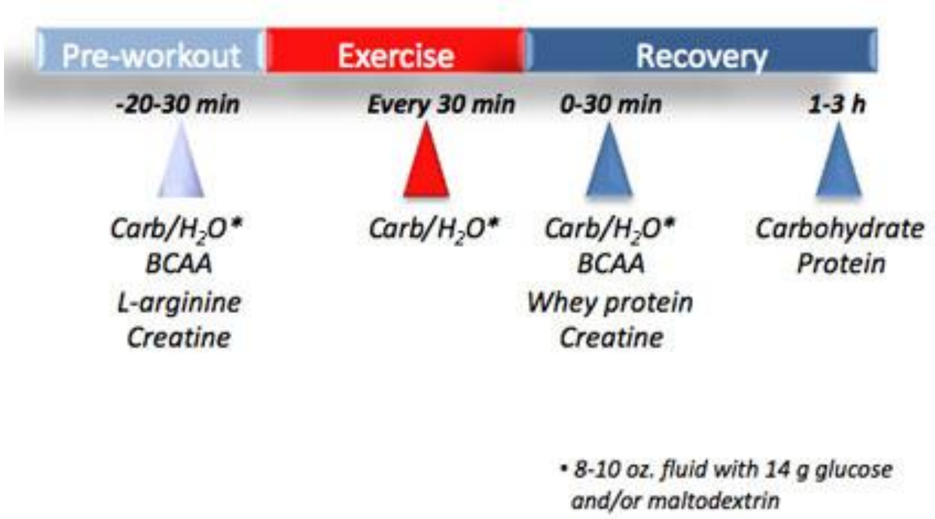
Training might only be 10% or less of total day!

- Nutrition hours after exercise
- Nutrition before bed (nocturnal nutrition)
- Nutrition first thing in the morning

What does Nutrient Timing Mean?

If the answer is YES to some, many or all of the above:

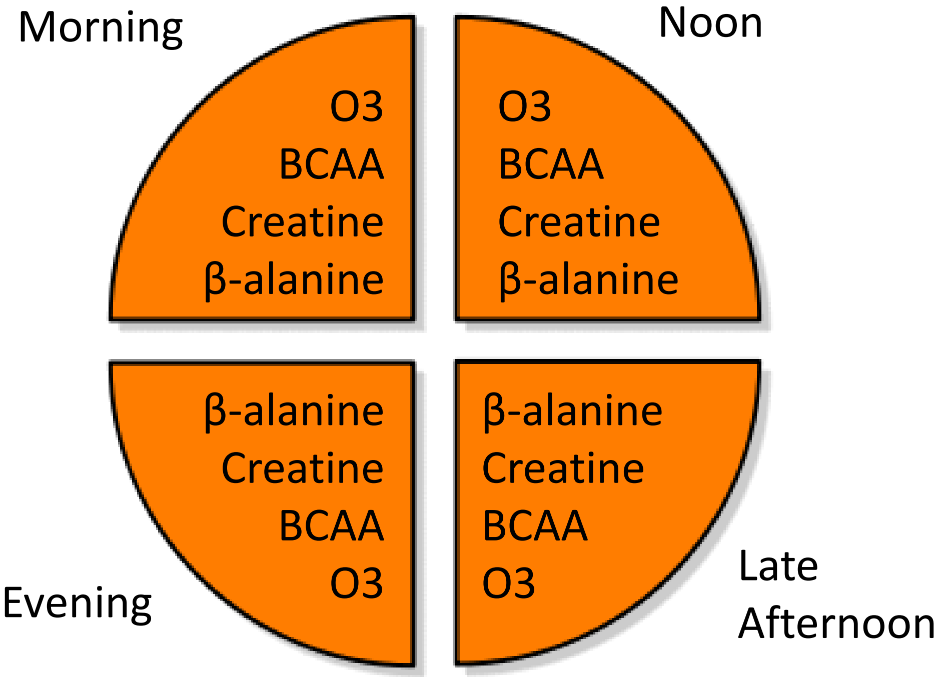
- What?
- How much?
- Who?
- Factors?
- Considerations?



What does Nutrient Timing Mean?

The Science of Split Doses

- Calories
- Carbs
- Protein
- BCAAs
- Specialized Fats
- Creatine
- β-Alanine
- HMB
- Others



Morning

O3
BCAA
Creatine
β-alanine

Noon

O3
BCAA
Creatine
β-alanine

Evening

β-alanine
Creatine
BCAA
O3

Late Afternoon

β-alanine
Creatine
BCAA
O3

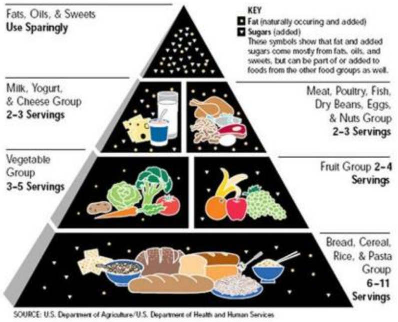
AP Photo/Keith Srakocic

Food vs Supplements

Food 1st

- Food can provide all of necessary nutrients to optimize performance
  - Protein, carbohydrates, BCAAs, creatine, β-alanine, HMB, carnitine, EPA (20:5 ω-3), caffeine
  - DSHEA is based on naturally occurring elements, molecules and compounds

Goodbye Pyramid.......Hello My Plate

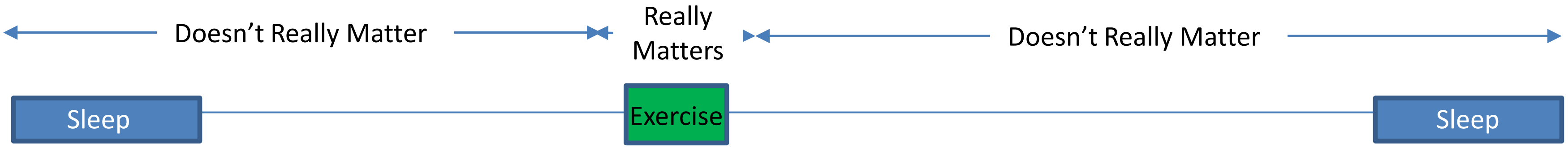

Fats, Oils, & Sweets
Use Sparingly
KEY
Fat (naturally occuring and added)
Sugars (added)
These symbols show that fat and added sugars come mostly from fats, oils, and sweets, but can be part of or added to foods from the other food groups as well.
Milk, Yogurt, & Cheese Group
2-3 Servings
Meat, Poultry, Fish, Dry Beans, Eggs, & Nuts Group
2-3 Servings
Vegetable Group
3-5 Servings
Fruit Group 2-4 Servings
Bread, Cereal, Rice, & Pasta Group
6-11 Servings

SOURCE: U.S. Department of Agriculture/U.S. Department of Health and Human Services

Supplements 2nd

- Can diet provide the optimal (efficacious) levels?
  - Multiple grams – creatine, β-alanine, ω-3s, etc
- Can diet strategically deliver key nutrients without excessive volume, calories and non-targeted nutrients

The History of Nutrient Timing



Doesn't Really Matter

Really Matters

Doesn't Really Matter

Sleep

Exercise

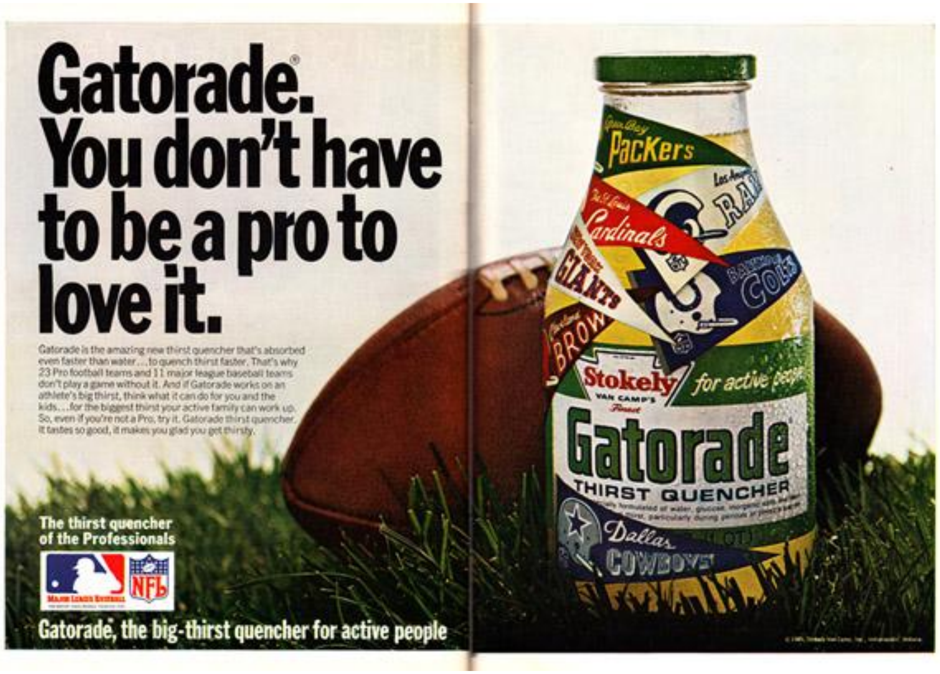
Sleep

Mid-Late 20th Century Nutrient Timing

- **Focused on During**

Gatorade - 8 ounce serving

- 50 calories
- 0 fat calories
- 0 grams of fat
- 110mg of sodium
- 30mg of potassium
- 14 grams of carbohydrates
- 14 grams of sugar
- 0 grams of protein.



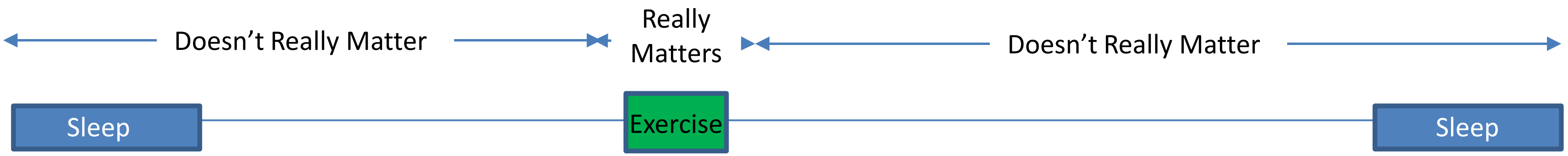
Gatorade. You don't have to be a pro to love it.

Gatorade is the amazing new thirst quencher that's absorbed even faster than water… to quench thirst faster. That's why 23 Pro football teams and 11 major league baseball teams don't play a game without it. And if Gatorade works on an athlete's big thirst, think what it can do for you and the kids… for the biggest thirst your active family can work up. So, even if you're not a Pro, try it. Gatorade thirst quencher. It tastes so good, it makes you glad you get thirsty.

The thirst quencher of the Professionals

Gatorade, the big-thirst quencher for active people

The History of Nutrient Timing



Doesn't Really Matter

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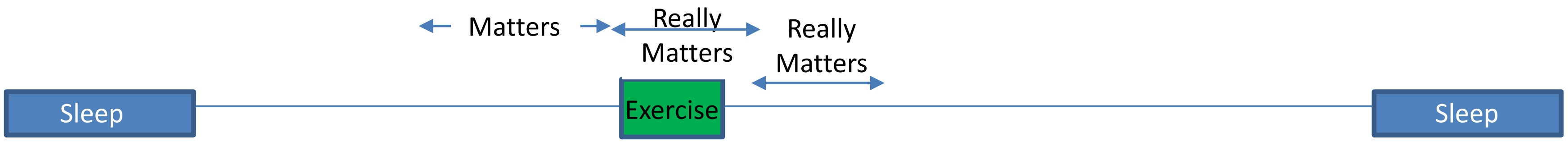


Matters

Really Matters

Really Matters

Sleep

Exercise

Sleep

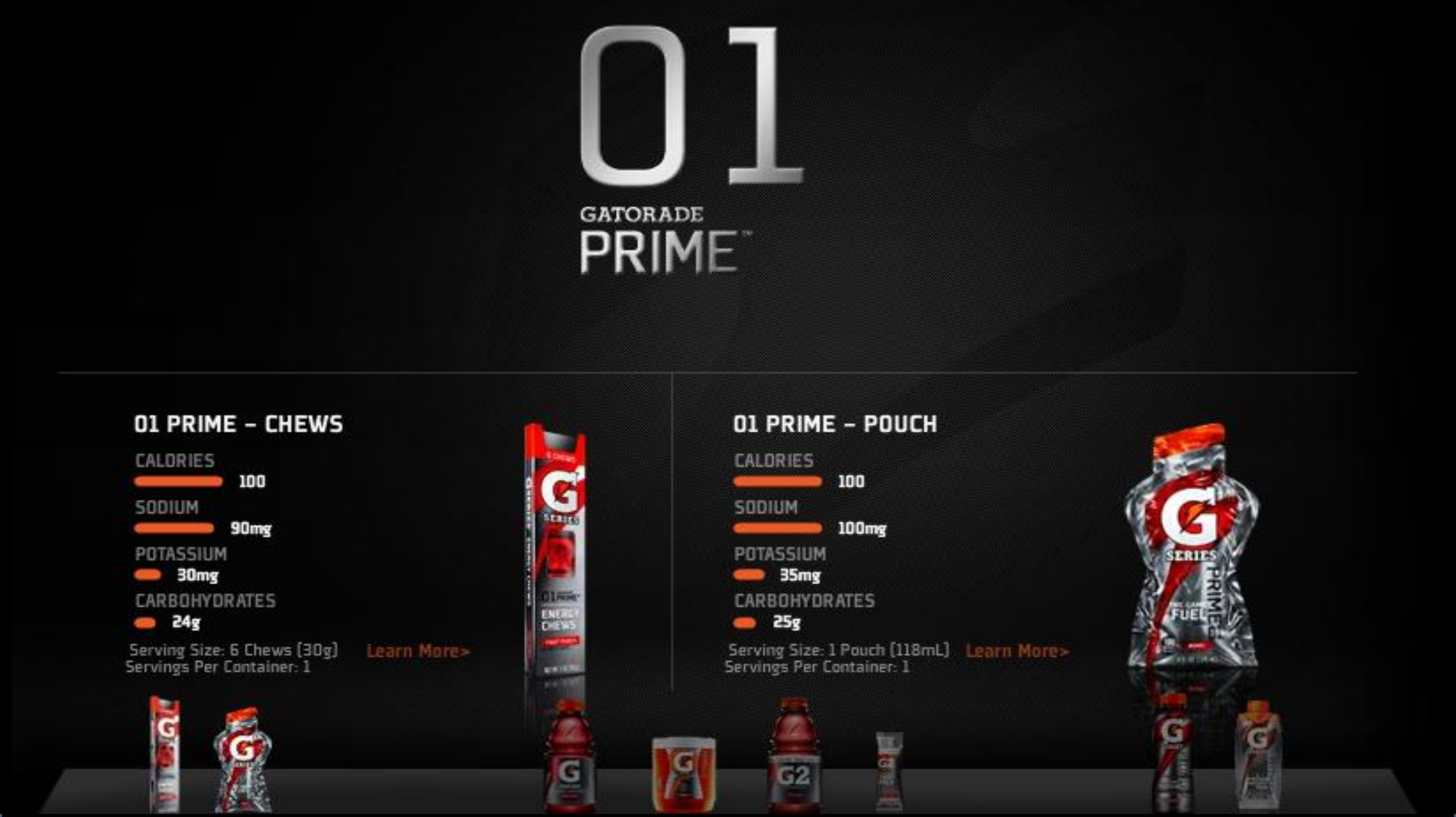
G SERIES

G Series fuels your body before, during and after practice, training or competition. Be fueled to achieve your best every step of the way with this new line of products.

The BEFORE

The DURING

The AFTER



01

GATORADE
PRIME™

01 PRIME – CHEWS

CALORIES	100
SODIUM	90mg
POTASSIUM	30mg
CARBOHYDRATES	24g

Serving Size: 6 Chews (30g)
Servings Per Container: 1

Learn More>

01 PRIME – POUCH

CALORIES	100
SODIUM	100mg
POTASSIUM	35mg
CARBOHYDRATES	25g

Serving Size: 1 Pouch (118mL)
Servings Per Container: 1

Learn More>

G SERIES

01 PRIME - POUCH

ENERGY TO FUEL ATHLETES

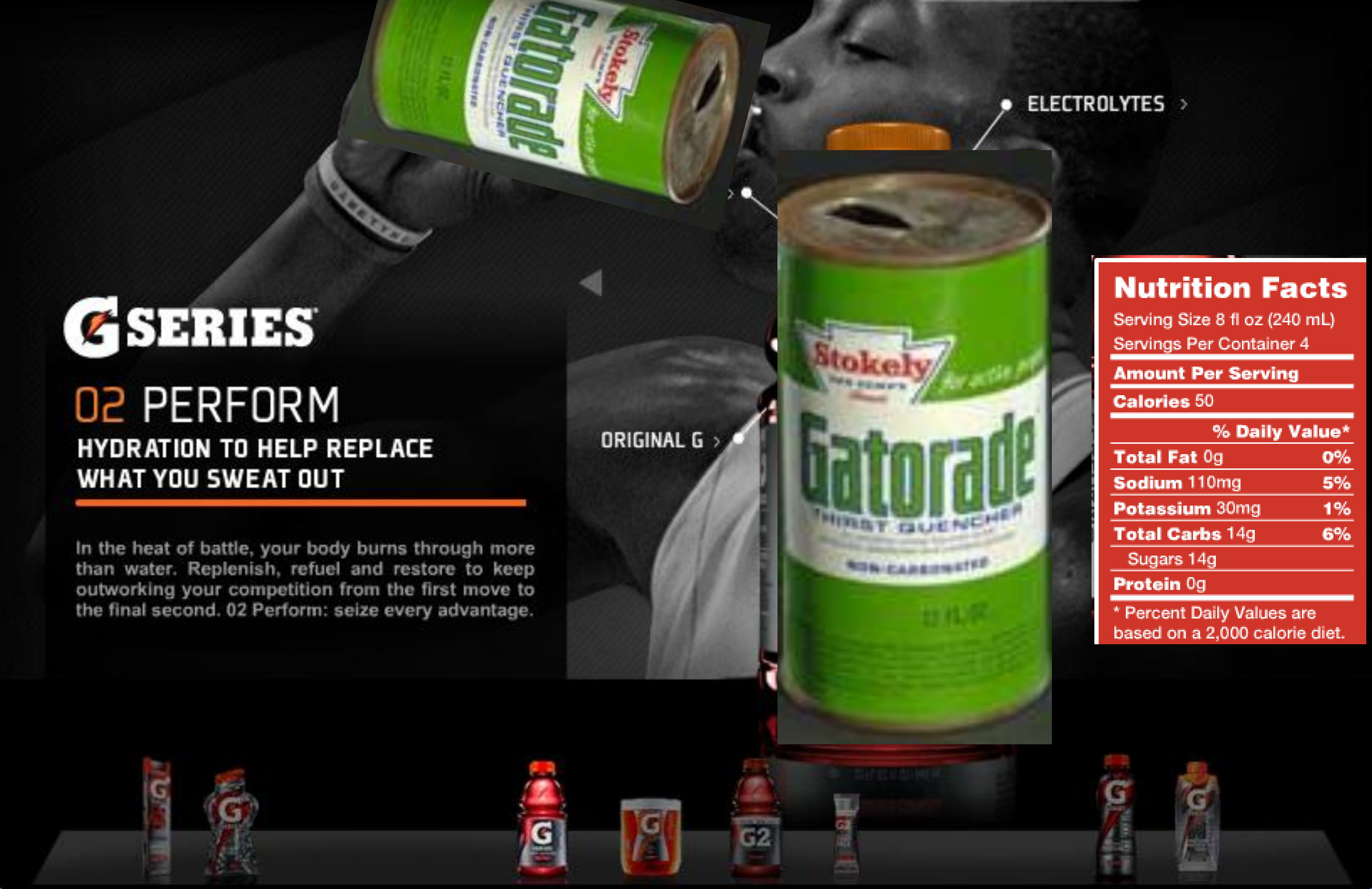
Your game is a product of preparation. Its the culmination of every hour sacrificed. Before you hit the weights or take the field, give your body the energy it needs to help realize its full potential. 01 Prime: own the first move.

Nutrition Facts

Serving Size 1 pouch (118 mL)
Servings Per Container 1

Amount Per Serving	
Calories 100	
Calories from Fat 0	
	% Daily Value*
Total Fat 0g	**0%**
Saturated Fat 0g	**0%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 110mg	**5%**
Potassium 35mg	**1%**
Total Carbs 25g	**8%**
Dietary Fiber 0g	**1%**
Sugars 23g	
Protein 0g	
Vitamin A	**0%**
Vitamin C	**0%**
Calcium	**0%**
Iron	**0%**
Niacin	**10%**
Vitamin B6	**10%**
Pantothenic Acid	**10%**

* Percent Daily Values are based on a 2,000 calorie diet.



G SERIES

02 PERFORM

HYDRATION TO HELP REPLACE WHAT YOU SWEAT OUT

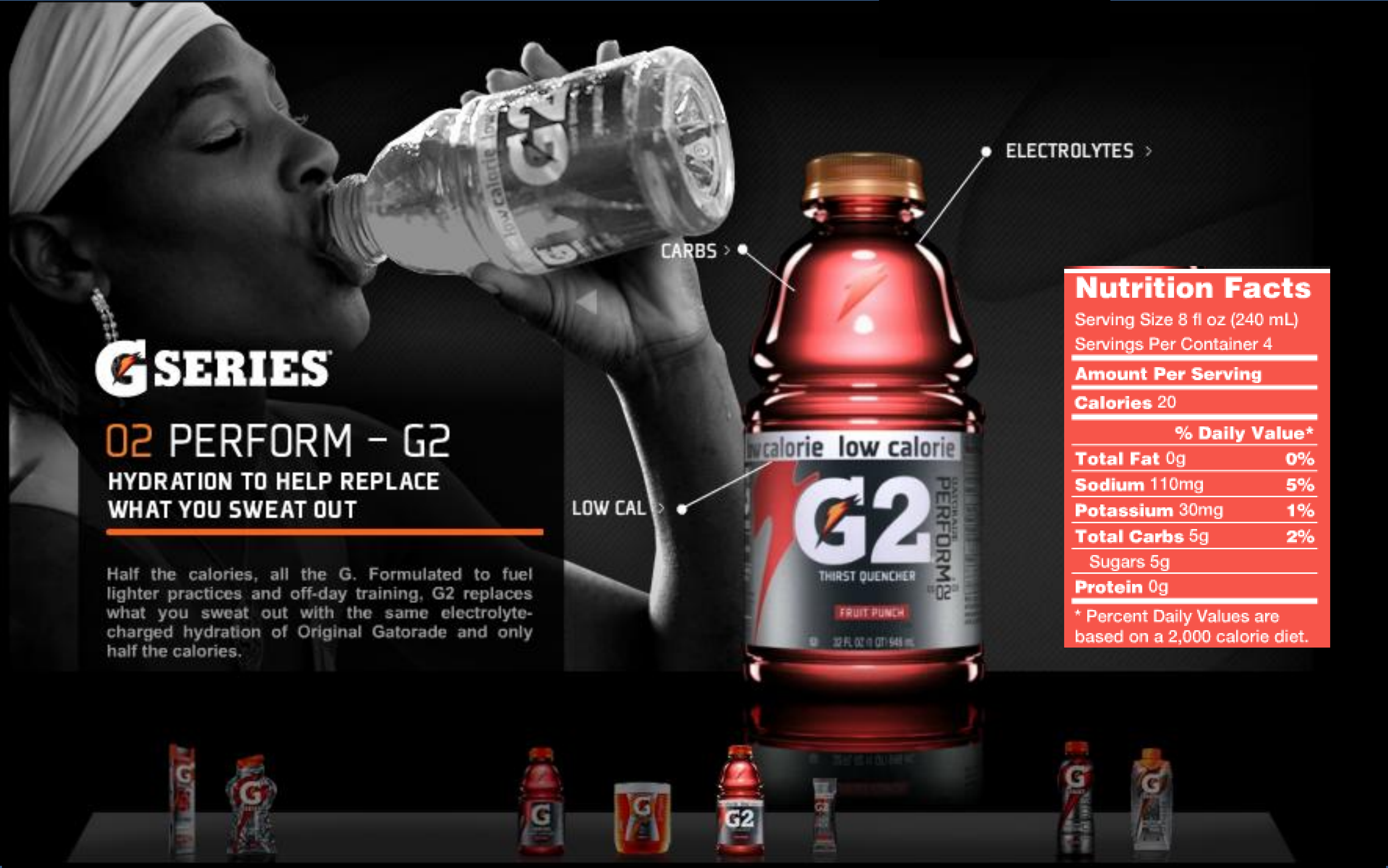
In the heat of battle, your body burns through more than water. Replenish, refuel and restore to keep outworking your competition from the first move to the final second. 02 Perform: seize every advantage.

Nutrition Facts

Serving Size 8 fl oz (240 mL)
Servings Per Container 4

Amount Per Serving	
Calories 50	
	% Daily Value*
Total Fat 0g	**0%**
Sodium 110mg	**5%**
Potassium 30mg	**1%**
Total Carbs 14g	**6%**
Sugars 14g	
Protein 0g	

* Percent Daily Values are based on a 2,000 calorie diet.



G SERIES

02 PERFORM – G2

HYDRATION TO HELP REPLACE WHAT YOU SWEAT OUT

Half the calories, all the G. Formulated to fuel lighter practices and off-day training, G2 replaces what you sweat out with the same electrolyte-charged hydration of Original Gatorade and only half the calories.

Nutrition Facts

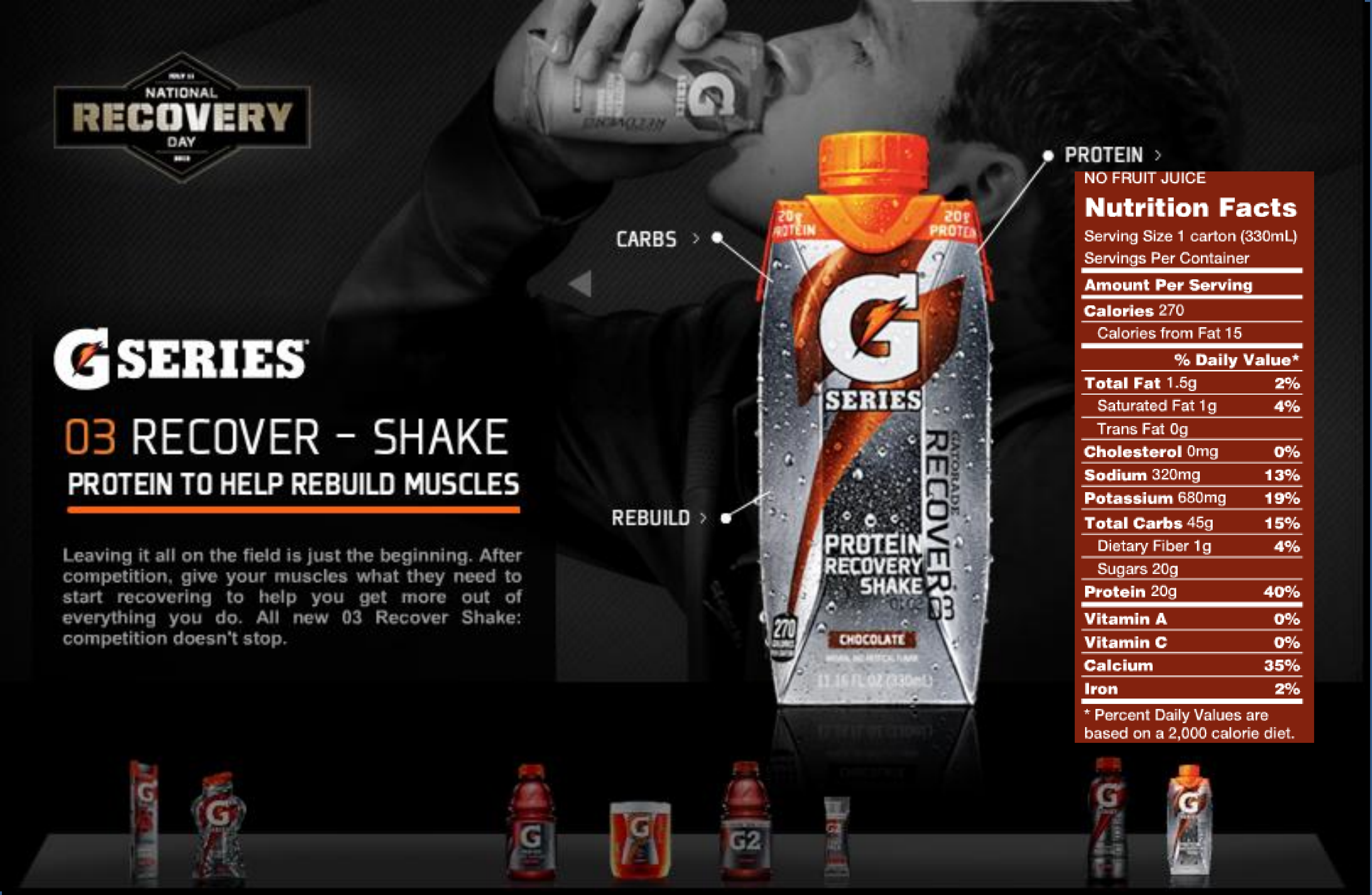
Serving Size 8 fl oz (240 mL)
Servings Per Container 4

Amount Per Serving

Calories 20

	% Daily Value*
Total Fat 0g	**0%**
Sodium 110mg	**5%**
Potassium 30mg	**1%**
Total Carbs 5g	**2%**
Sugars 5g	
Protein 0g	

* Percent Daily Values are based on a 2,000 calorie diet.



G SERIES

03 RECOVER – SHAKE

PROTEIN TO HELP REBUILD MUSCLES

Leaving it all on the field is just the beginning. After competition, give your muscles what they need to start recovering to help you get more out of everything you do. All new 03 Recover Shake: competition doesn't stop.

CARBS ›

REBUILD ›

PROTEIN ›

NO FRUIT JUICE

Nutrition Facts

Serving Size 1 carton (330mL)
Servings Per Container

Amount Per Serving

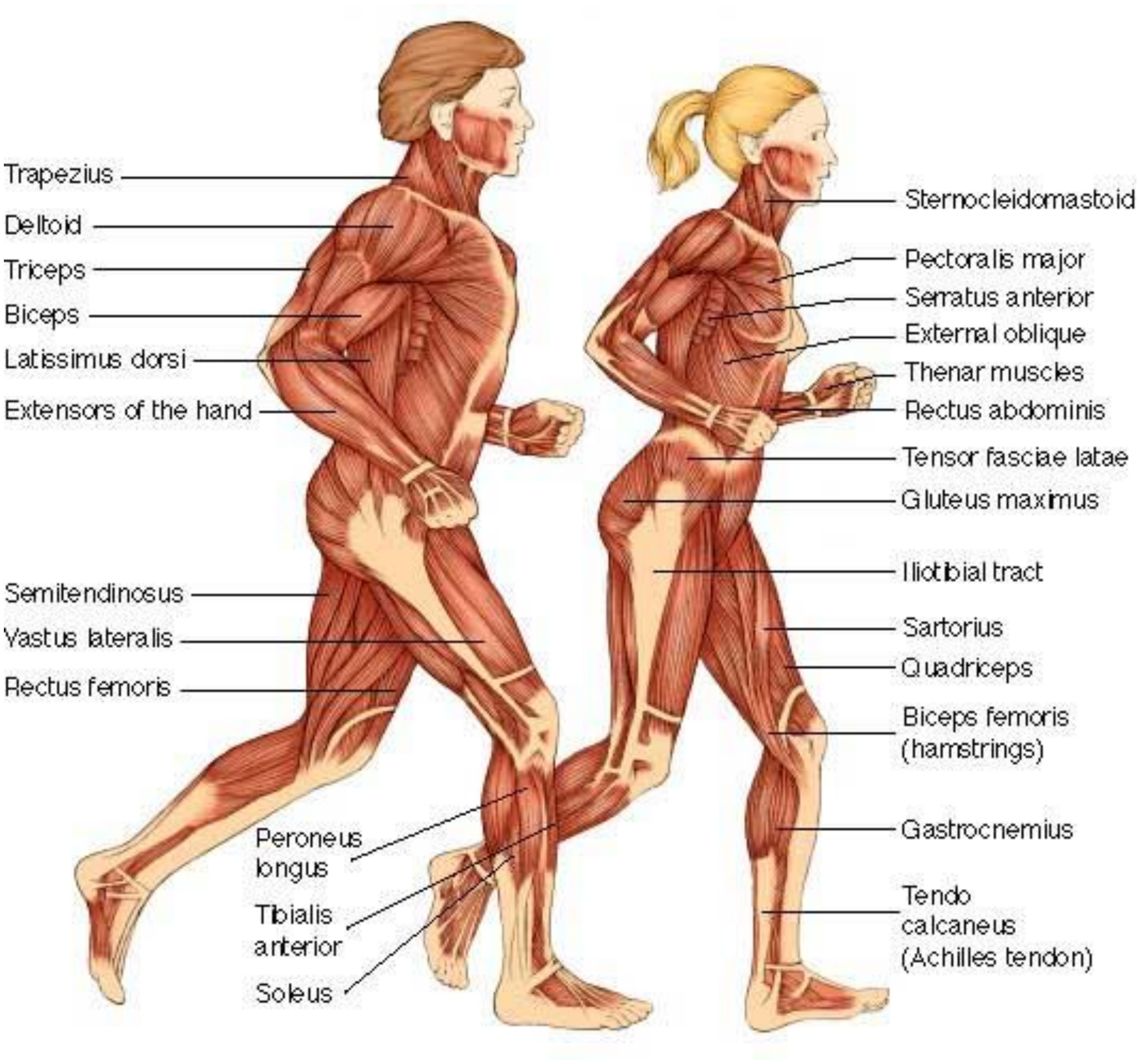
Calories 270
Calories from Fat 15

	% Daily Value*
Total Fat 1.5g	**2%**
Saturated Fat 1g	**4%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 320mg	**13%**
Potassium 680mg	**19%**
Total Carbs 45g	**15%**
Dietary Fiber 1g	**4%**
Sugars 20g	
Protein 20g	**40%**
Vitamin A	**0%**
Vitamin C	**0%**
Calcium	**35%**
Iron	**2%**

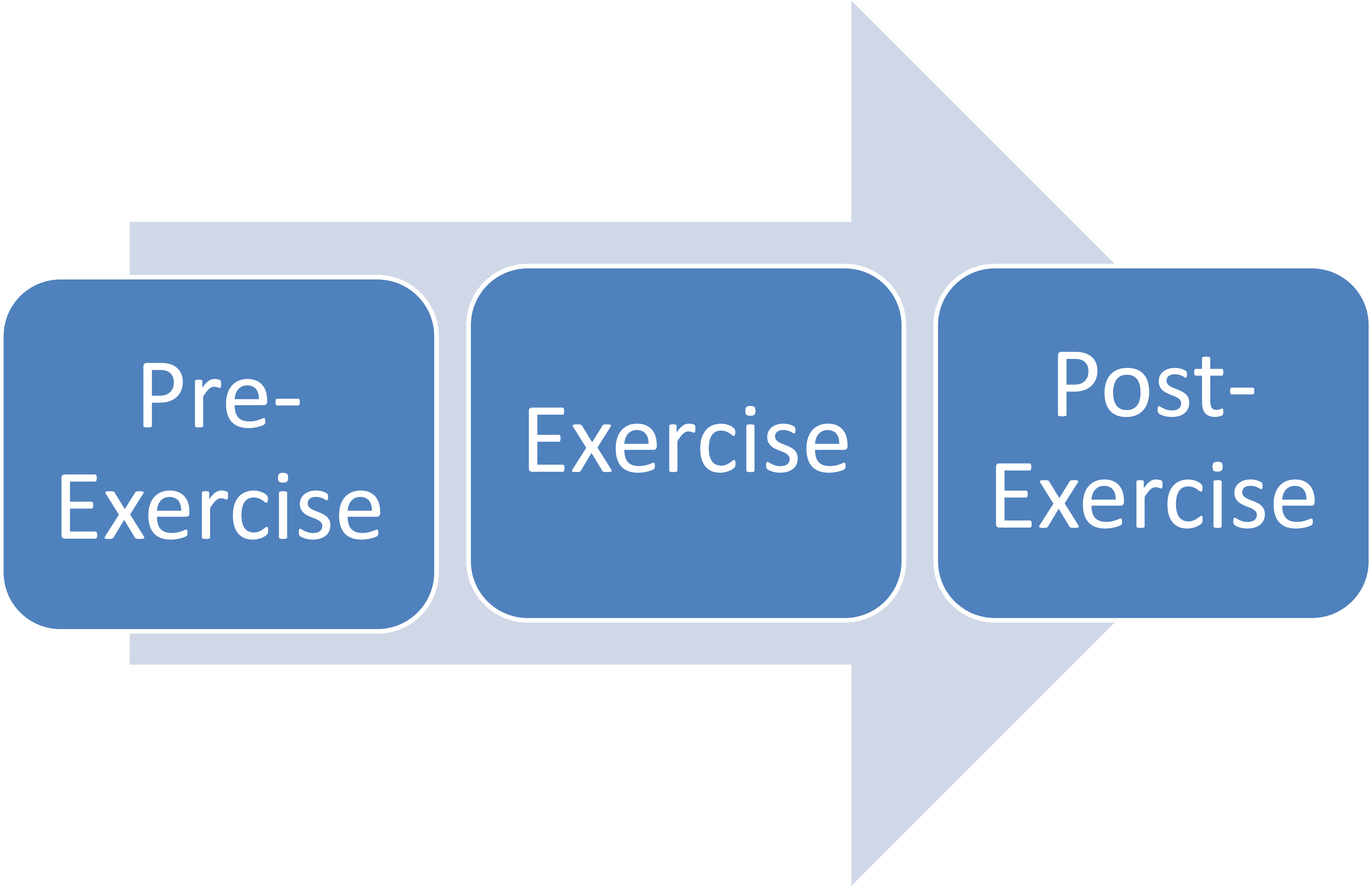
* Percent Daily Values are based on a 2,000 calorie diet.

Skeletal Muscle

- 72-73% H_2O
- 20-22% protein
- >80% protein (dry weight)
- Contractile proteins
- Enzymes and other proteins (e.g. collagen)
- Protein Turnover
- Metabolic Monster



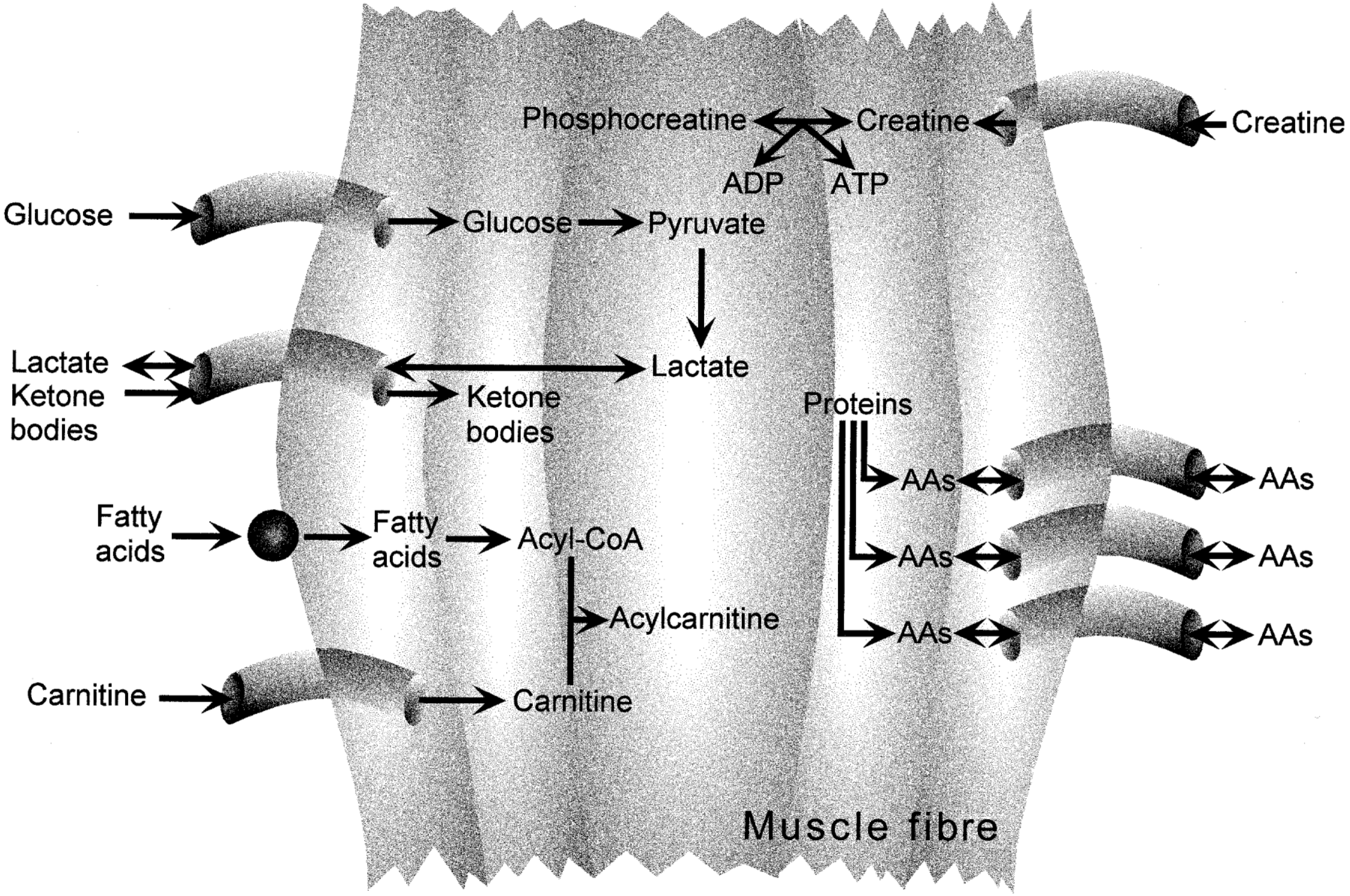
EXERCISE P/P/R



Pre-Exercise

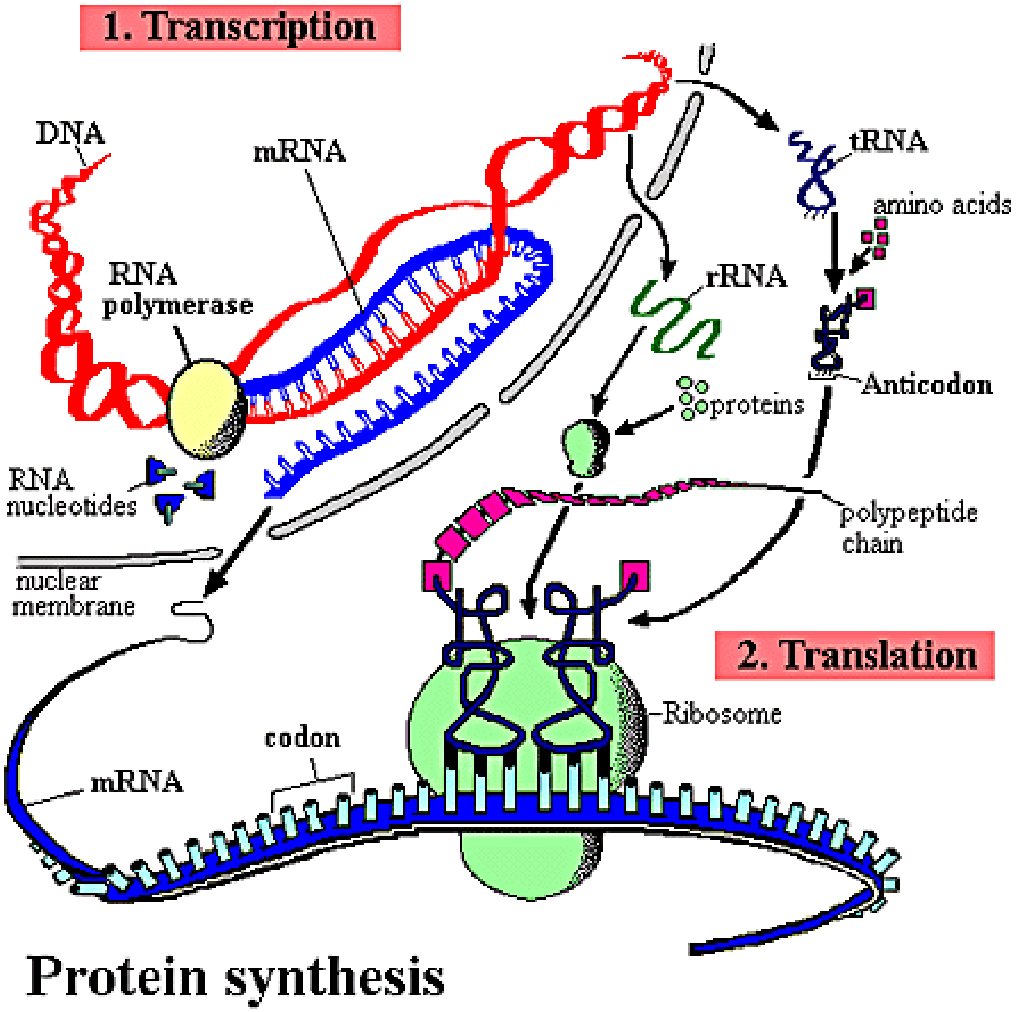
Exercise

Post-Exercise



GLUT4 (insulin/exercise), GLUT1 (basal needs) and GluT5 (fructose)

Protein Manufacturing



- **DNA** (the blueprint)
- **mRNA** (the message)
- **Ribosomes** (the manufacturing site)
- **Protein** (the product)

PRE•PERFORMANCE

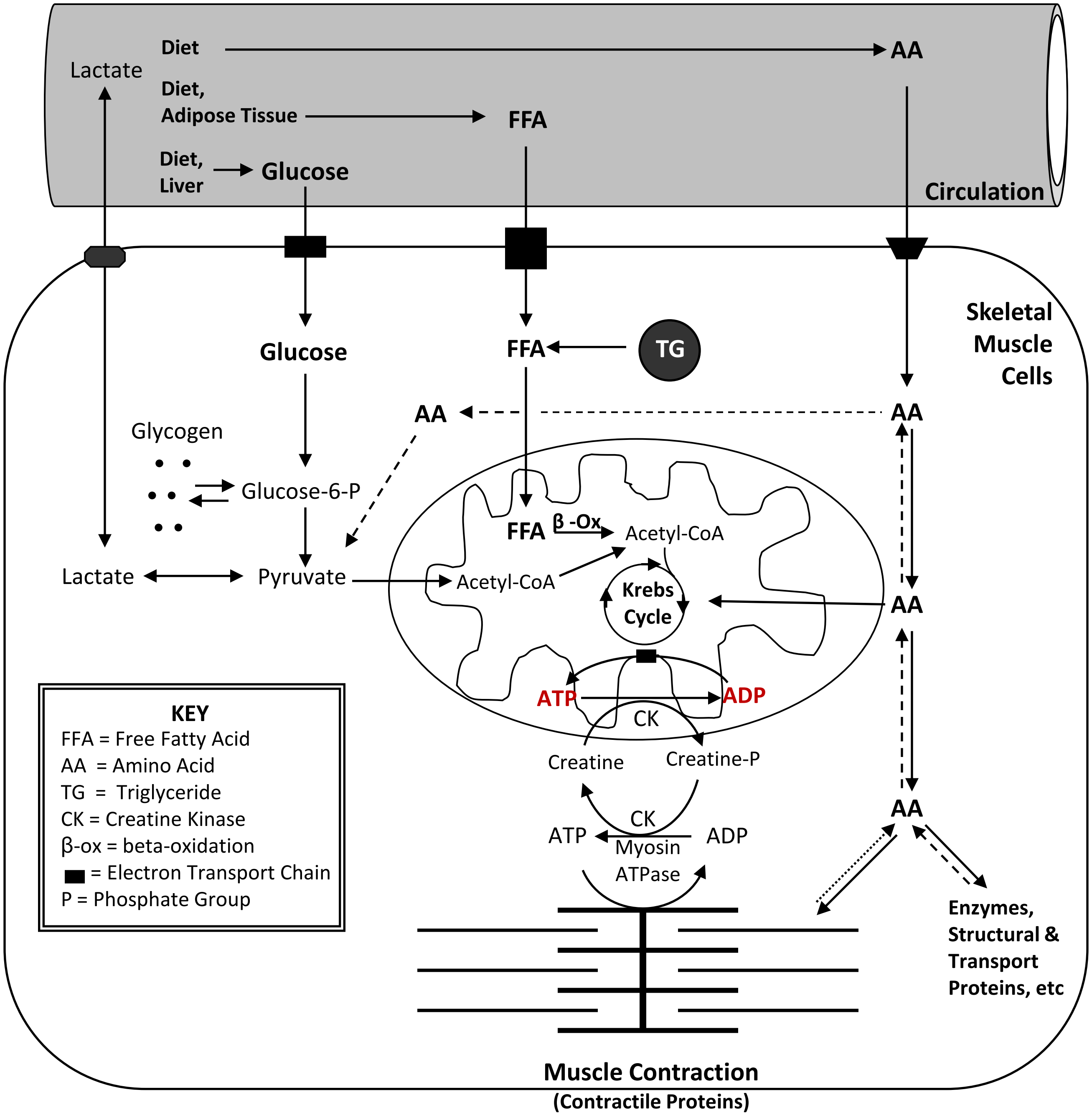
Nutrient Infusion into bloodstream:

- Normal and augmented physiological response and uptake in muscle:
  - Energy substrates (blood, intramuscular pool and storage)
  - Building blocks of structural/functional components
  - Metabolic support molecules
  - Buffers and precursors

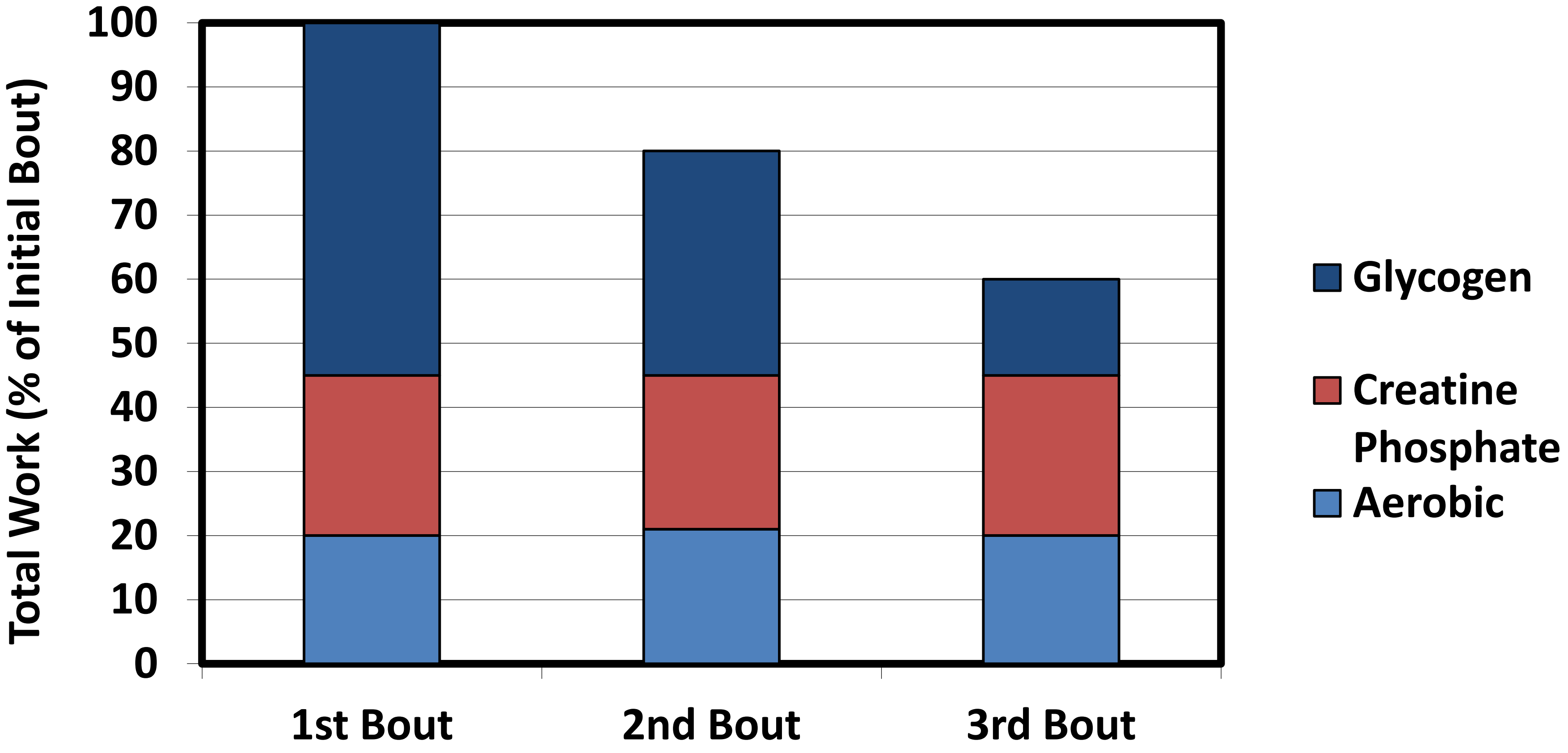
- CNS stimulation:
  - Energy
  - Focus
  - Intensity

PERFORMANCE

- Mechanical Contraction
    - Deformation of myofibers
- Energy Depletion
    - Glycogen
- Hormonal Modifications
- Immune Response
    - Inflammation


Lactate
Diet
AA
Diet,
Adipose Tissue
FFA
Diet,
Liver
Glucose
Circulation
Skeletal
Muscle
Cells
Glucose
FFA
TG
AA
AA
Glycogen
Glucose-6-P
FFA
β -Ox
Acetyl-CoA
Lactate
Pyruvate
Acetyl-CoA
Krebs
Cycle
AA
ATP
ADP
CK
Creatine
Creatine-P
CK
ATP
ADP
Myosin
ATPase
AA
Enzymes,
Structural &
Transport
Proteins, etc
Muscle Contraction
(Contractile Proteins)
KEY
FFA = Free Fatty Acid
AA = Amino Acid
TG = Triglyceride
CK = Creatine Kinase
β-ox = beta-oxidation
■ = Electron Transport Chain
P = Phosphate Group

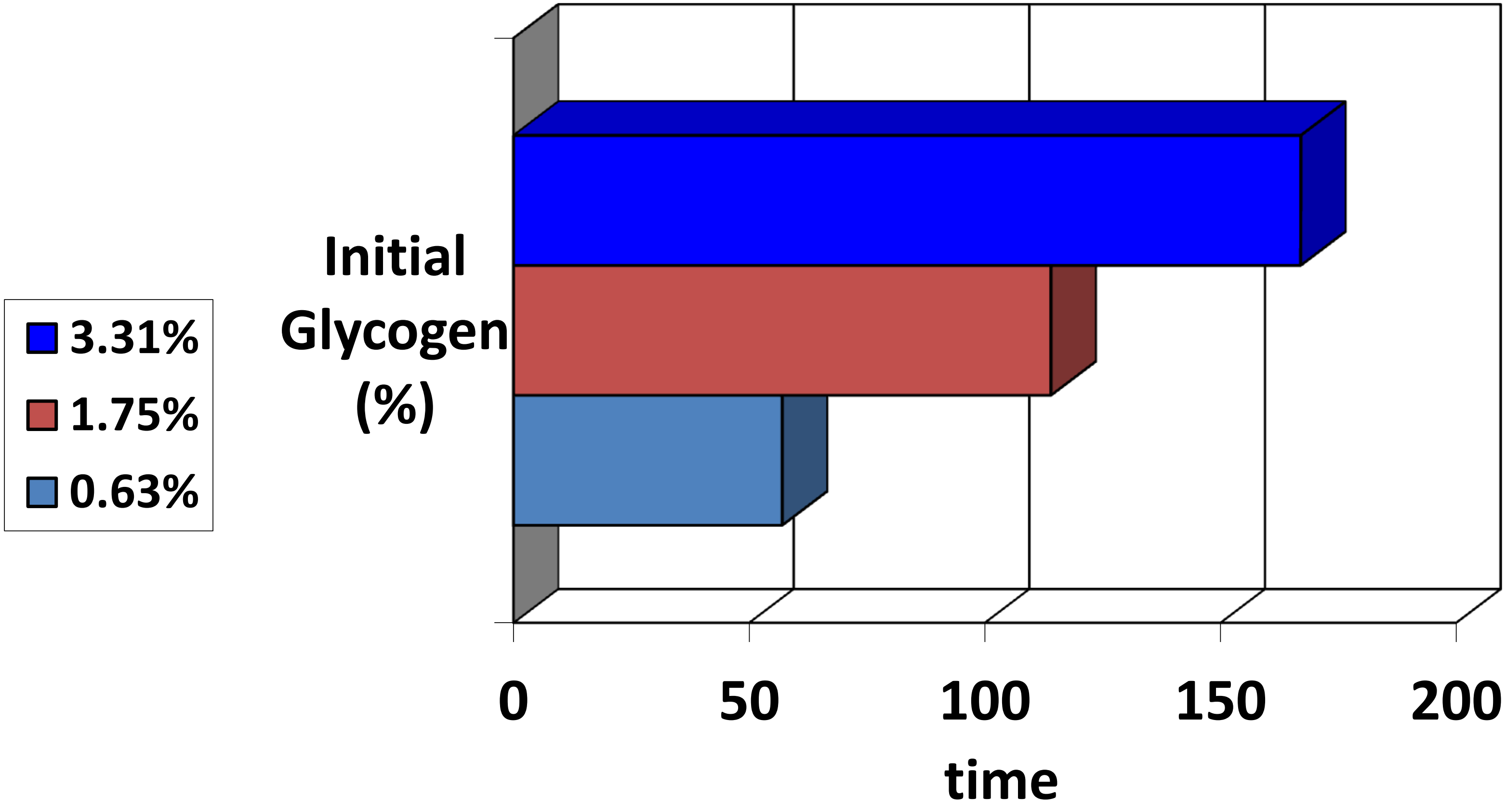
Energy Contribution During Three Bouts of Maximal Isokinetic Cycling



- 30s maximal isokinetic cycling at 100 rpm
- 4 minutes of rest in between

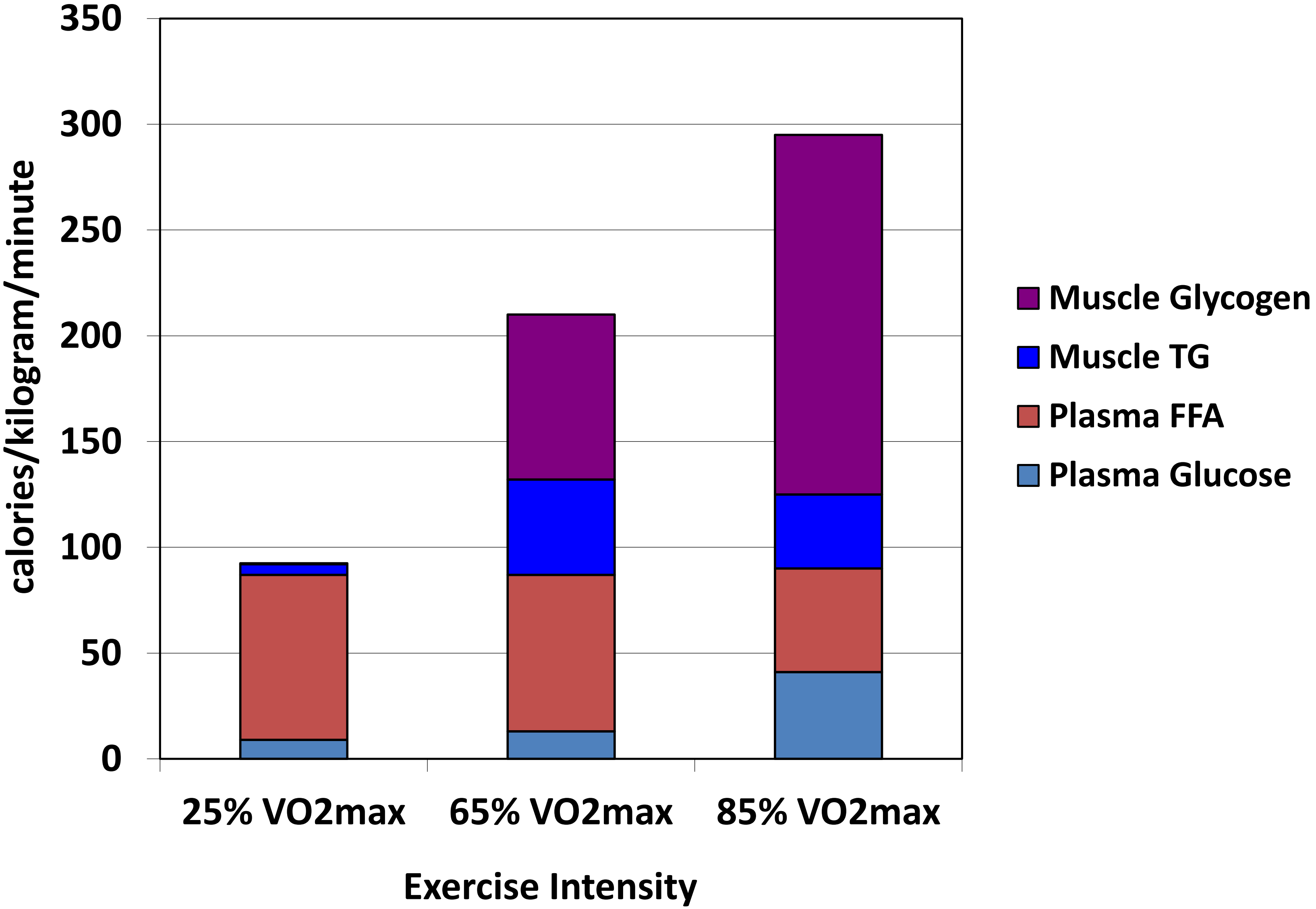
Spriet et al J. Appl. Physiol. 66:8-13, 1989

Submaximal Time till Exhaustion

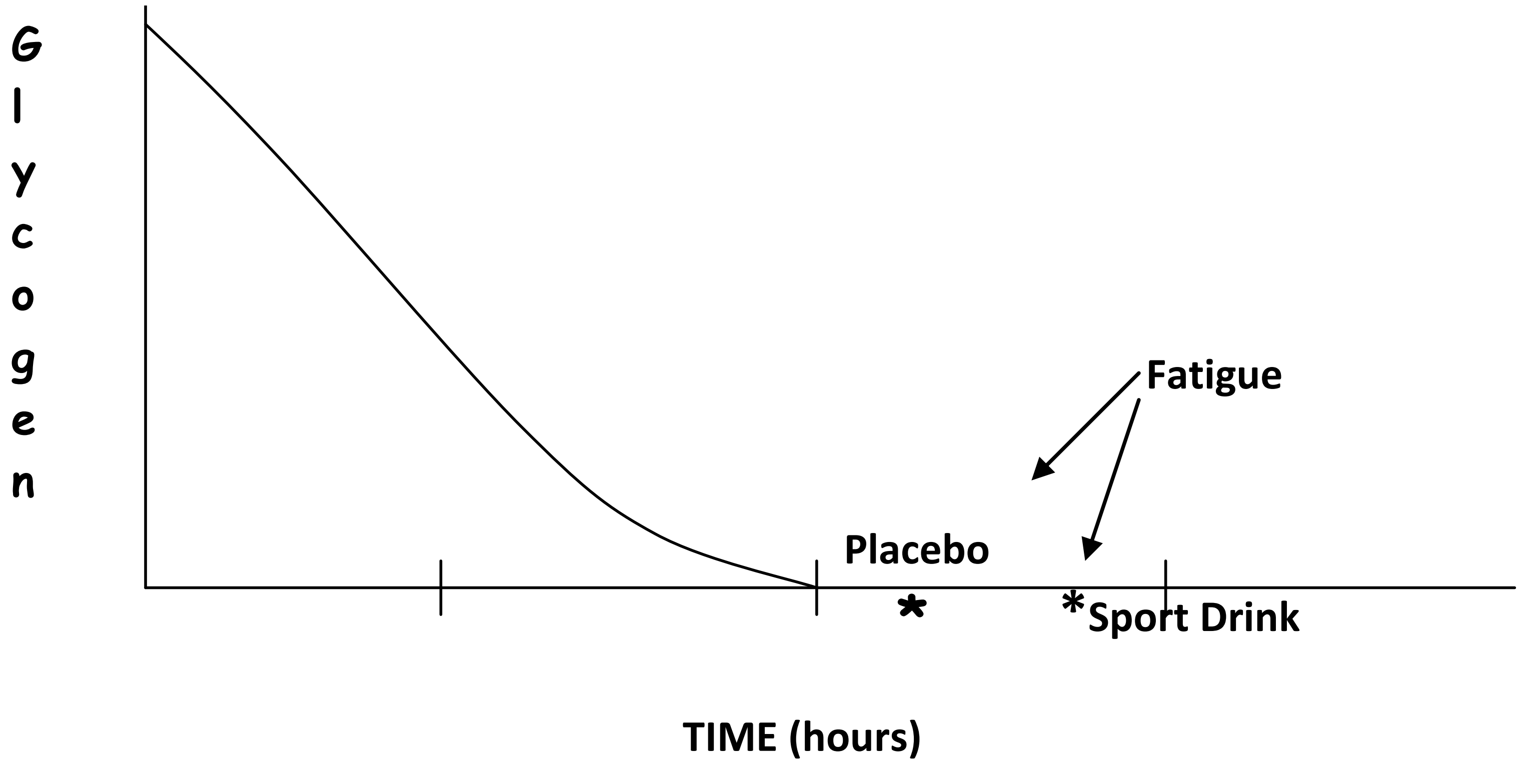


Starting w/ more glycogen

Berstrom et al, *Acta Physiol Scand* 71:140-150, 1967.



Romjin et al, Am J. Phys. 265:E380-E391, 1993.



* Endurance Athletes

  - sport drink is important as late carbohydrate source

* Intermittent Athletes (soccer, football)

  - sport drink can help maintain glycogen stores longer

Comparison of Carbohydrate and Protein Content of Common Commercially Available Sport Drinks

Ingredients per 8 oz.	Carbohydrate Content	Carbs	Protein	Calories	Sodium	Potassium	Other Nutrients	Caffeine
Accelerade® (RTD)	6 %	15 g	4 g	80	120 mg	15 mg	Vitamin E, Calcium	0 mg
Amino Vital Endurance® (RTD)	5.5%	13 g	2.4 g	40	110 mg	35 mg	Vitamin C, Magnesium, Calcium	0 mg
Cytomax® Performance Plus RTD	5 %	13 g	0 g	50	55 mg	30 mg	MCT, Vitamin C, Chromium,	0 mg
Gatorade G®02 Perform	6 %	14 g	0 g	50	110 mg	30 mg		0 mg
Gatorade G®02 Endurance Formula	6 %	14 g	0 g	50	200 mg	90 mg		0 mg
Gatorade G®03 Recover	3%	7g	8g	60	120 mg	45 mg	Calcium	0 mg
Heed Performance	5%	13g	<1 g	50	20 mg	13 mg	Vitamin B6, Calcium, Chromium, Magnesium, Manganese Tyrosine, Carnosine, Glycine	0 mg
Powerade ION4®	6 %	14 g	0 g	50	100 mg	25 mg	Vitamin B3, B6 and B12, Calcium, Magnesium	0 mg
Vitargo S2 (RTM)	10%	23 g	0 g	90	0 mg	0 mg		0 mg

Amino Vital is a registered trademark of Ajinomoto.

Cytomax is a registered trademark of Cytosport, Inc.

Gatorade and Propel are registered trademarks of Stokely-Van Camp, Inc.

Heed is a registered trademark of Hammer Nutrition, Inc.

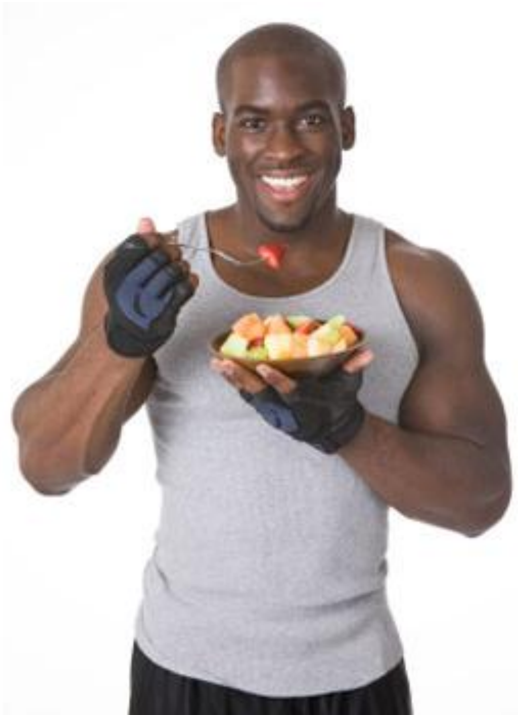
Powerade is a registered trademark of the Coca-Cola Company.

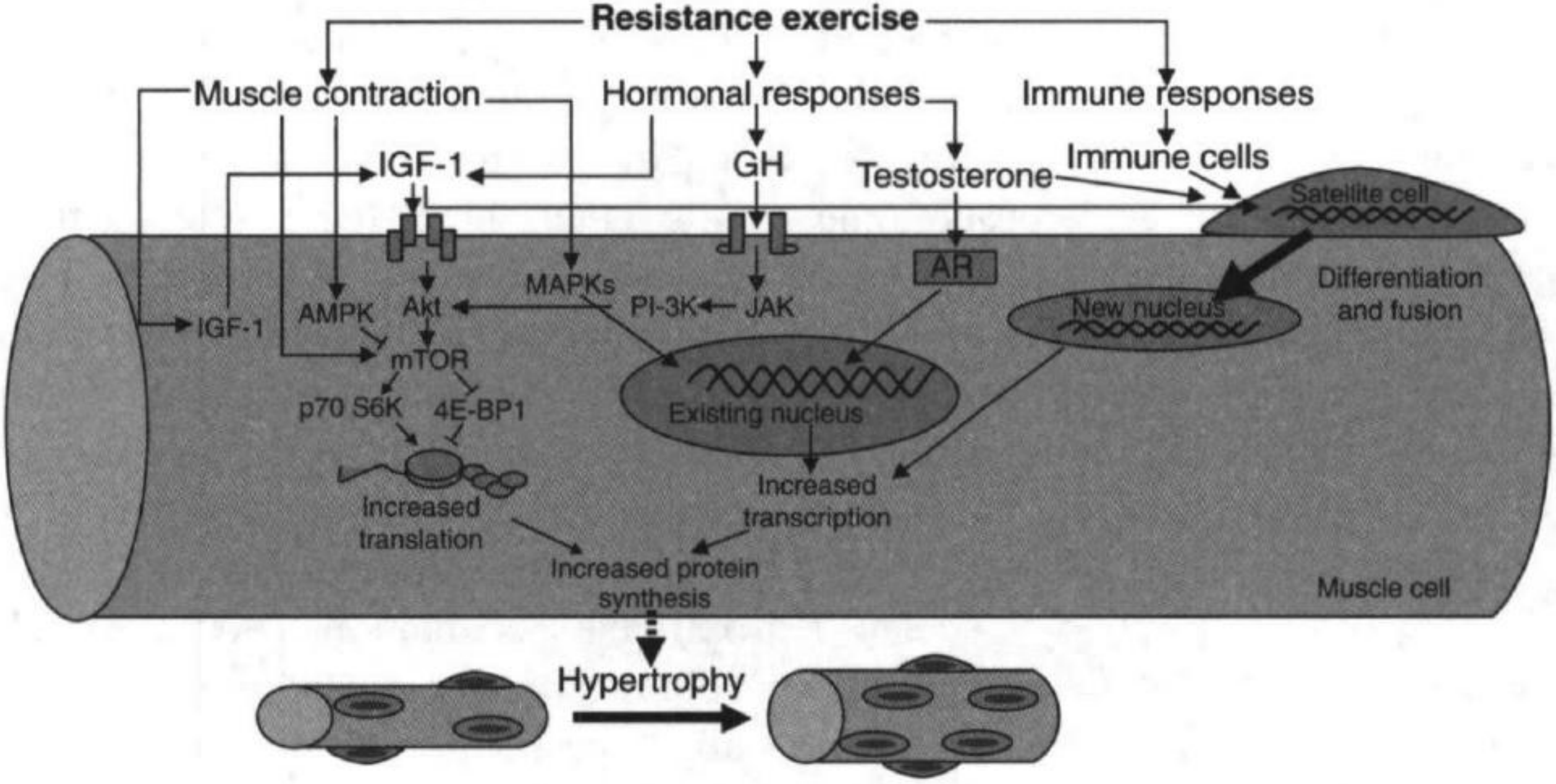
Propel is a registered trademark of PepsiCo.

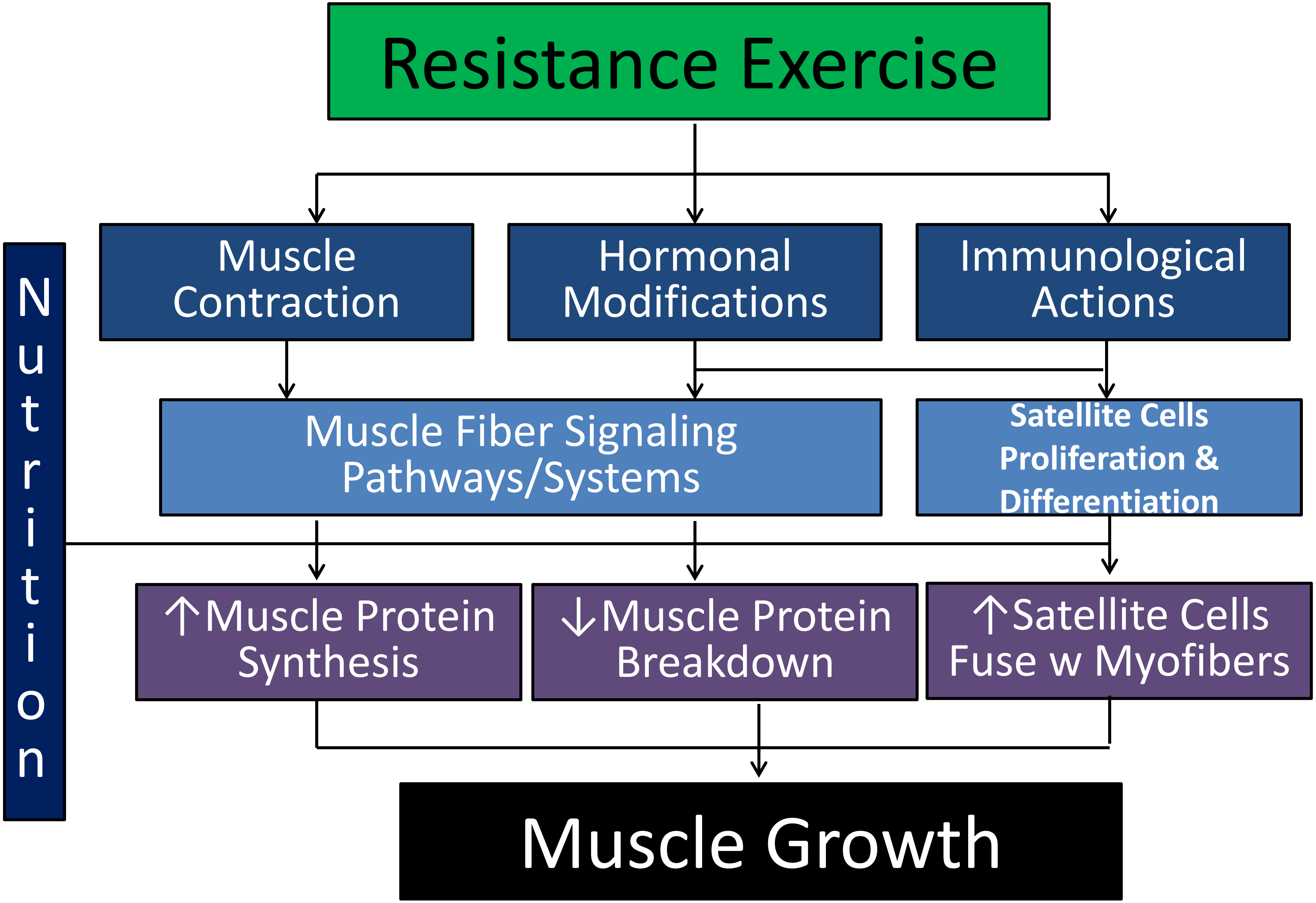
Vitargo is a registered trademark of SweCarb
Accelerade is a registered trademark of Mott's LLP.

Post Exercise

- Protein Synthesis Augmentation Maximization
  - Protein Kinase B – mTOR pathway
  - AMPK pathway
  - MAPK pathway
- Protein Breakdown Minimization
  - FOXO -> Ubiquitin ligases
- Recover energy stores
  - Glycogen
  - Fat
  - Amino acid Pool
- Reset pH and redox balance
- Manage damaged structural components
- Re-establish mineral balance and compartmentalization




Resistance exercise
Muscle contraction
Hormonal responses
Immune responses
IGF-1
GH
Testosterone
Immune cells
Satellite cell
IGF-1
AMPK
Akt
MAPKs
PI-3K
JAK
AR
Differentiation and fusion
New nucleus
mTOR
p70 S6K
4E-BP1
Existing nucleus
Increased translation
Increased transcription
Increased protein synthesis
Muscle cell
Hypertrophy



Resistance Exercise

Muscle Contraction

Hormonal Modifications

Immunological Actions

Muscle Fiber Signaling Pathways/Systems

Satellite Cells Proliferation & Differentiation

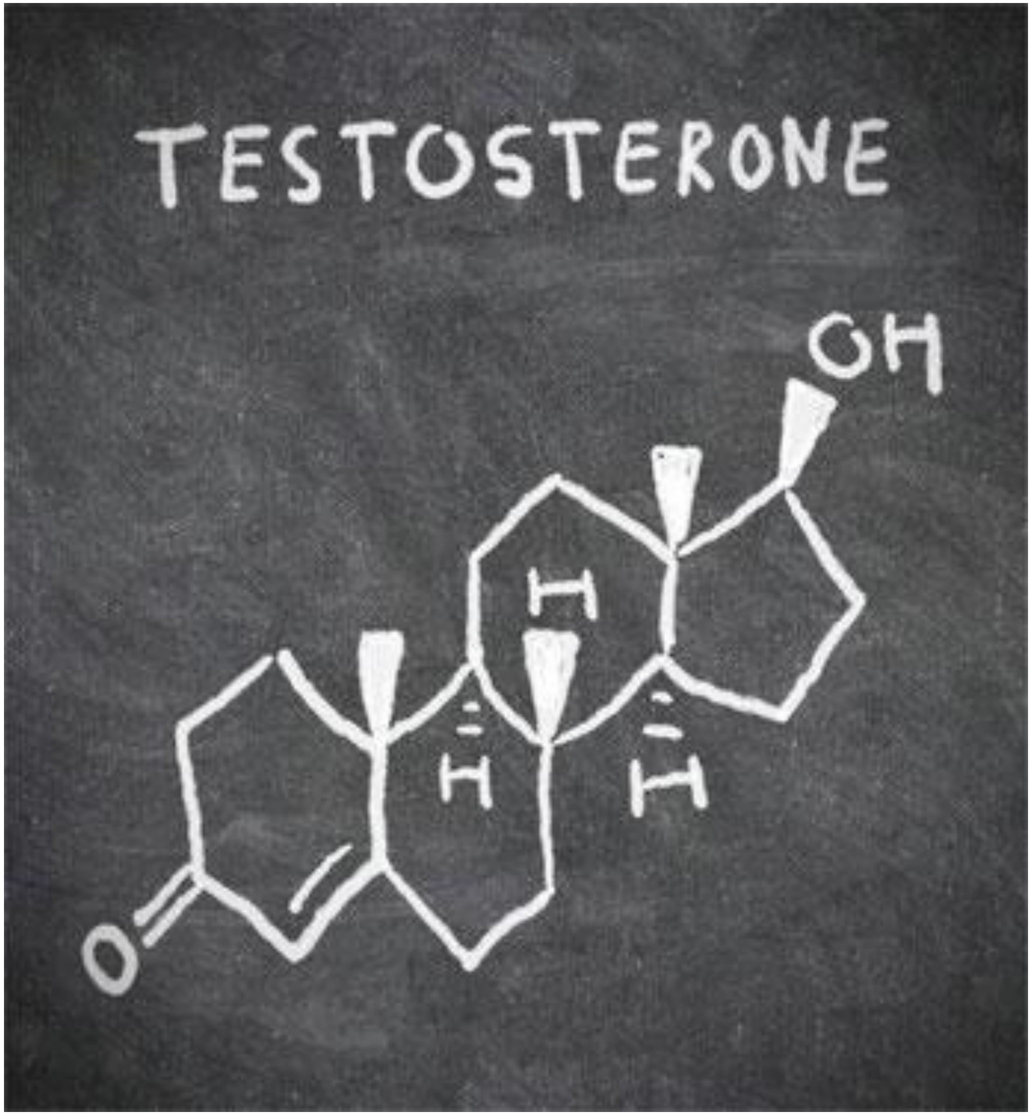
↑Muscle Protein Synthesis

↓Muscle Protein Breakdown

↑Satellite Cells Fuse w Myofibers

Muscle Growth

Nutrition



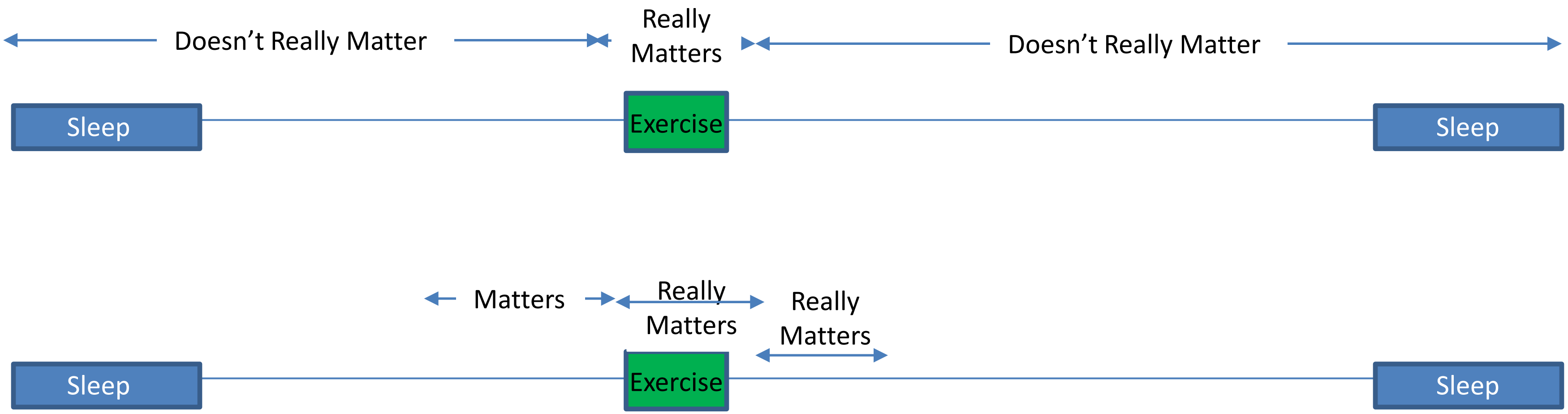
Hormonal Changes During Exercise

↑Testosterone

↑Growth Hormone

↑IGF-1

The History of Nutrient Timing



Doesn't Really Matter

Really Matters

Doesn't Really Matter

Sleep

Exercise

Sleep

Matters

Really Matters

Really Matters

Sleep

Exercise

Sleep

Nutrients Timing Target
Nutrient Examples

Before Exercise (Pre)

- Energy Nutrient for Performance (e.g. CHO, MCT, PRO, BCAA/EAA)
- Physiological Performance Support (e.g. β-alanine, AntiOx, B-Vits, O3FA, carnitine, FER)
- Mental/Cognitive Impact (e.g. Caffeine ingredients, Taurine, Glucuronolactone Citicholine)

During Exercise (Peri)

- Energy Nutrient for Performance (e.g. CHO, MCT, BCAA, PRO)
- Physiological Performance Support (e.g. B-vitamins, AntiOx, Carnitine, FER)
- Mental/Cognitive Impact (e.g. Caffeine ingredients)

After Exercise (Post)

- Muscle protein support (PRO, BCAA/EAA,, CHO, Creatine)

  Glycogen Recovery (e.g. CHO, PRO)
- Repair/Recovery Support (e.g. B-Vits, AntiOx)
- Rehydration Support (e.g. Recovery CHO/FER, glycerol)

Note: Before Exercise = <60 minutes prior to exercise; During Exercise = Onset/During training or competition, After Exercise = 30-60 minutes after completion and/or throughout the day after intense training or competition, CHO = Carbohydrate, PRO = Protein, BCAA = Branched Chain Amino Acids, EAA = Essential Amino Acids, AntiOx = Antioxidants, O3FA = Omega3 Fatty Acids, MCT = Medium Chain Triglycerides, FER = Fluid & Electrolyte Replacement.

Classic Study: Nutrient Timing Improves Muscle Hypertrophy

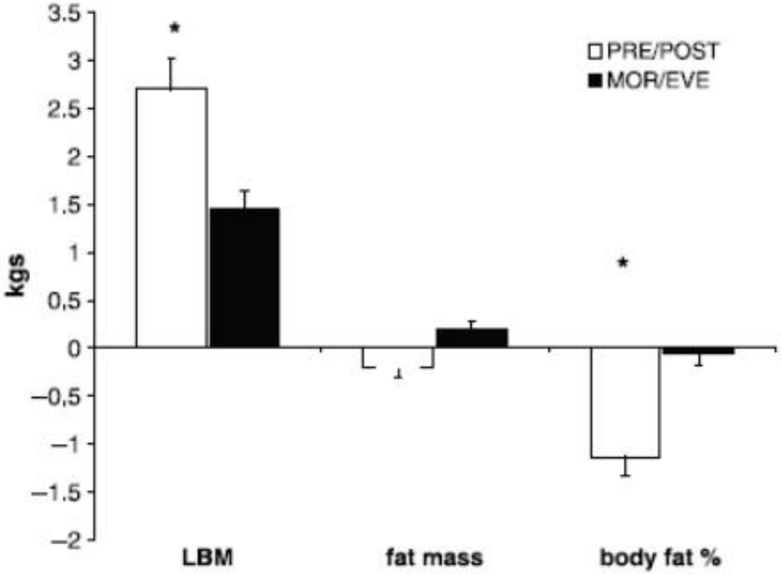


FIGURE 1—Body composition changes. * Greater change compared with MOR-EVE ($P < 0.05$).

Cribb & Hayes (2006). MSSE 38(11): 1918-1925.

- 23 males completed a 10-wk RT program.
- PRE/POST group consumed their "meal" immediately before and after RT.
- MOR/EVE took the same meal before breakfast and sleep.
- Meal ~ 32 g PRO, 34 g CHO, < 0.4 g FAT, and 5.6 g Cr.

Classic Study: Nutrient Timing Improves Muscular Strength

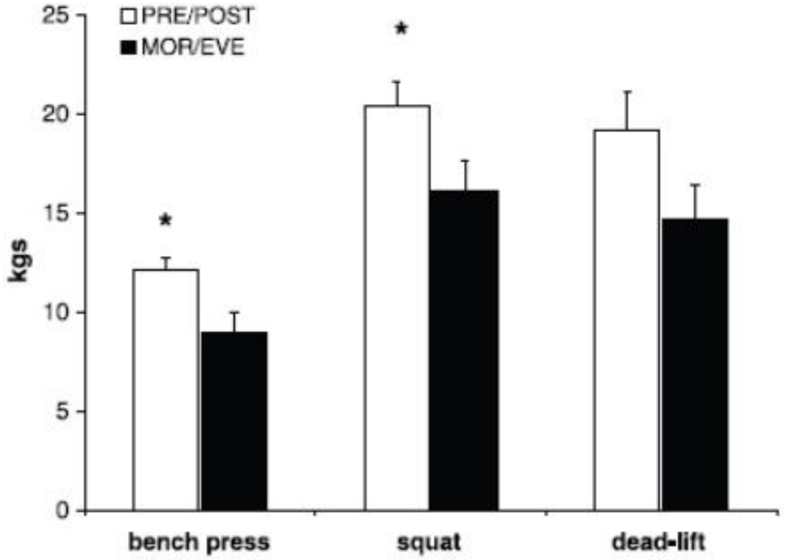
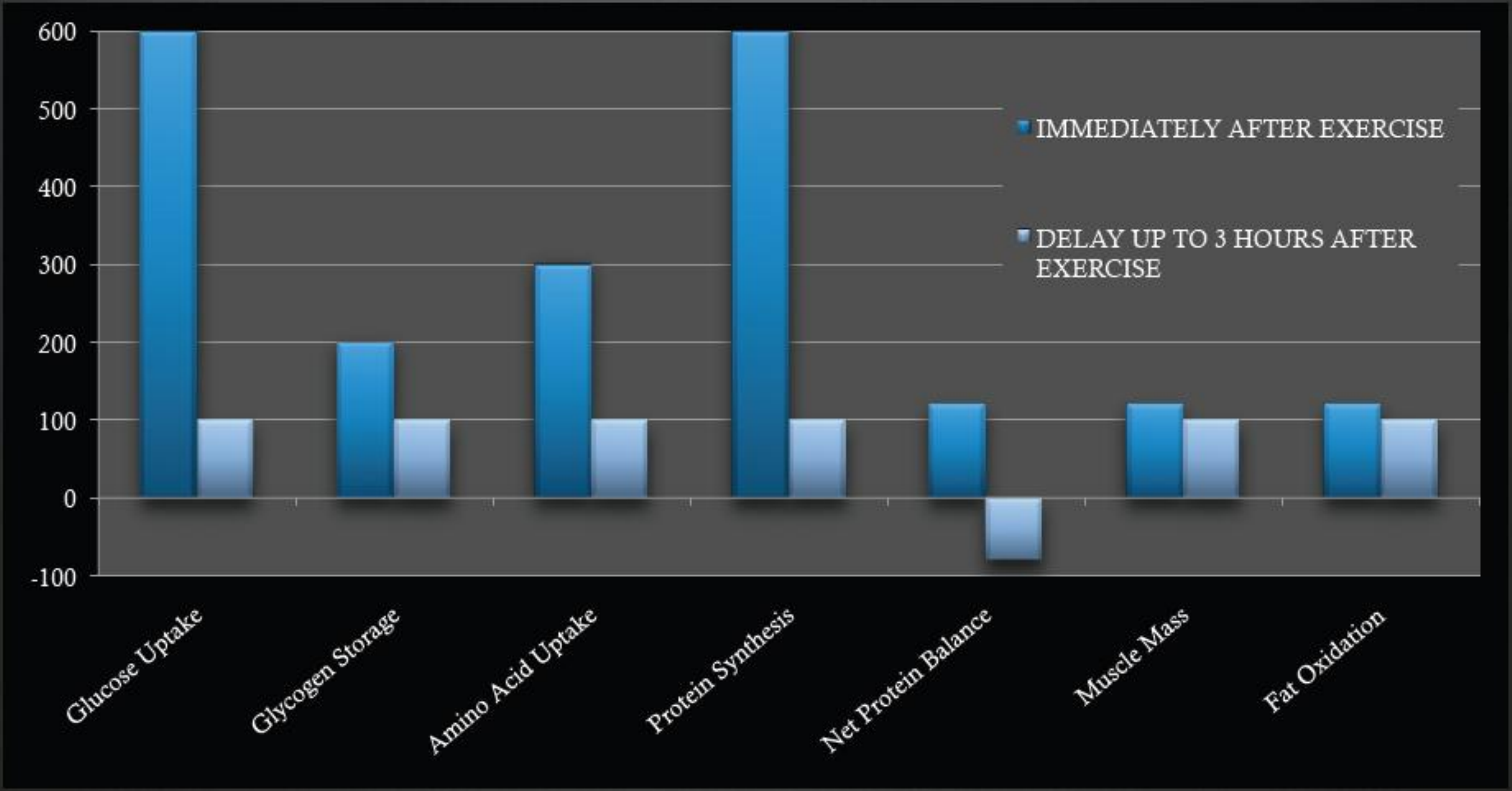


FIGURE 2—1RM strength changes. * Greater change compared with MOR-EVE ($P < 0.05$).

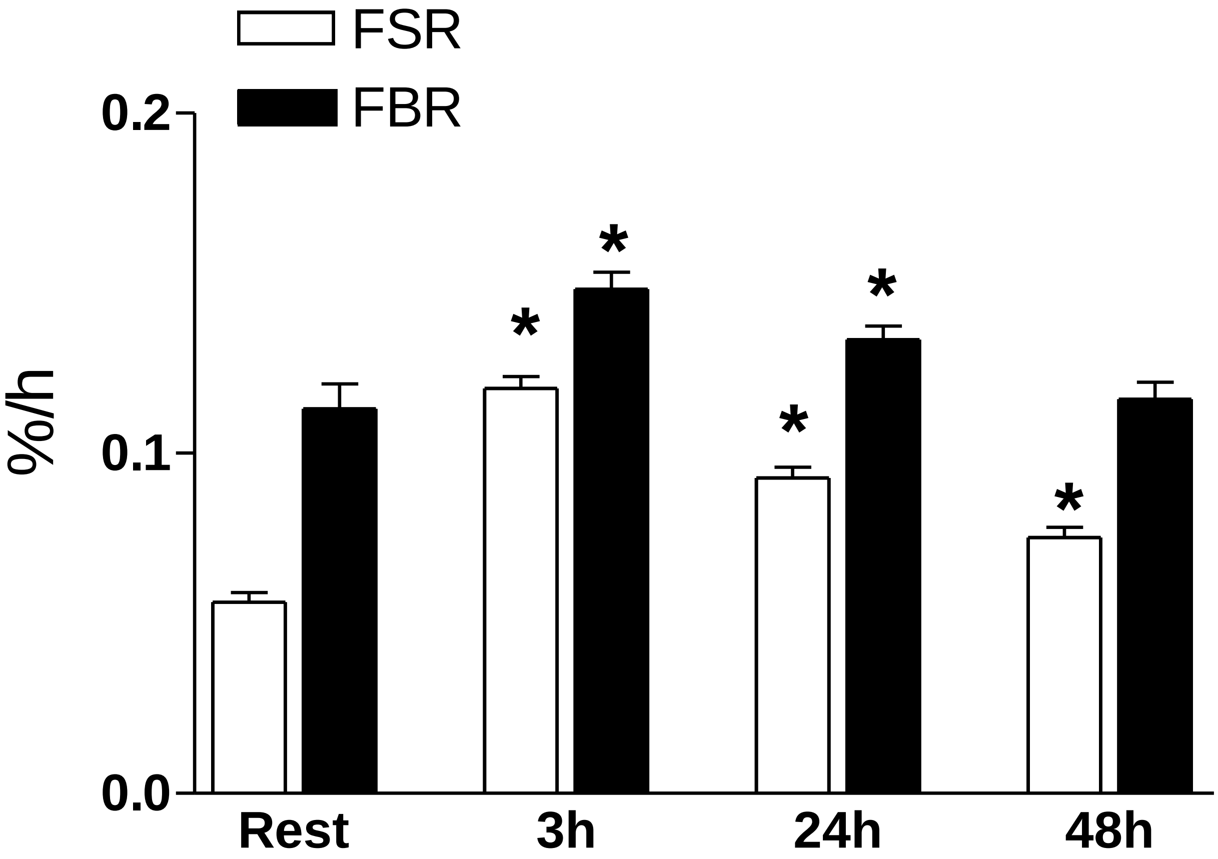
Cribb & Hayes (2006). MSSE 38(11): 1918-1925.

- The PRE/POST group also demonstrated **greater increases** in:
  - CSA of IIa and IIx muscle fibers
  - Contractile protein content
  - PCr and total creatine content
  - Muscle glycogen content
- The design of this study is particularly noteworthy as it applies to a wide sector of individuals engaged in RT.

Eat/Drink Before the Sweat Dries!



Theoretical Effects of Nutrient Delay on Muscle Anabolic Processes
(Adapted from Ivy & Portman, 2004)



- A bout of intense resistance training can endure for 24 hours or greater
- probably greater turnover in novice vs. trained individuals
- How can we maximize protein synthesis (FSR) & minimize breakdown (FBR)

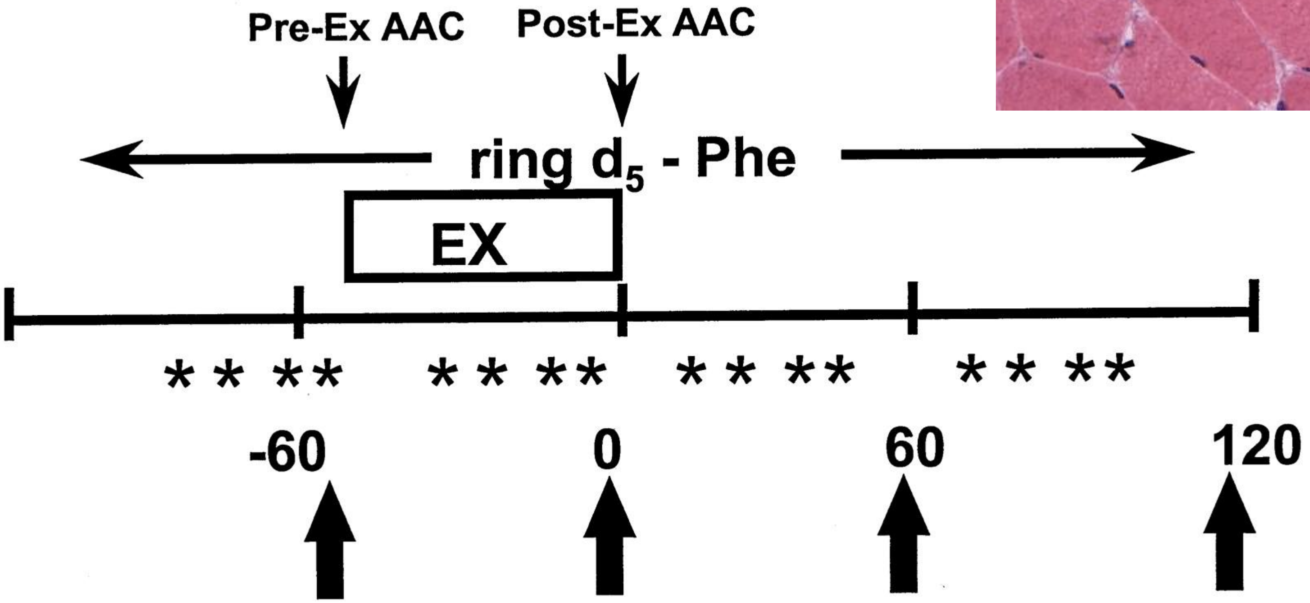
Pre vs. Post

Which is more important?

Study Protocol

⬆ **Muscle Biopsies**

* **AV Blood Sampling**



Pre-Ex AAC

Post-Ex AAC

ring d_5 - Phe

EX

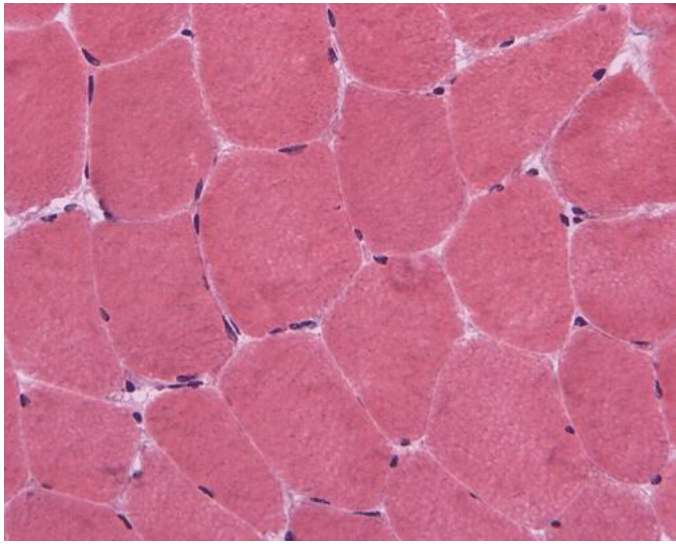
* * ** * * ** * * ** * * **

-60

0

60

120



Tipton K D et al. Am J Physiol Endocrinol Metab 2001;281:E197-E206

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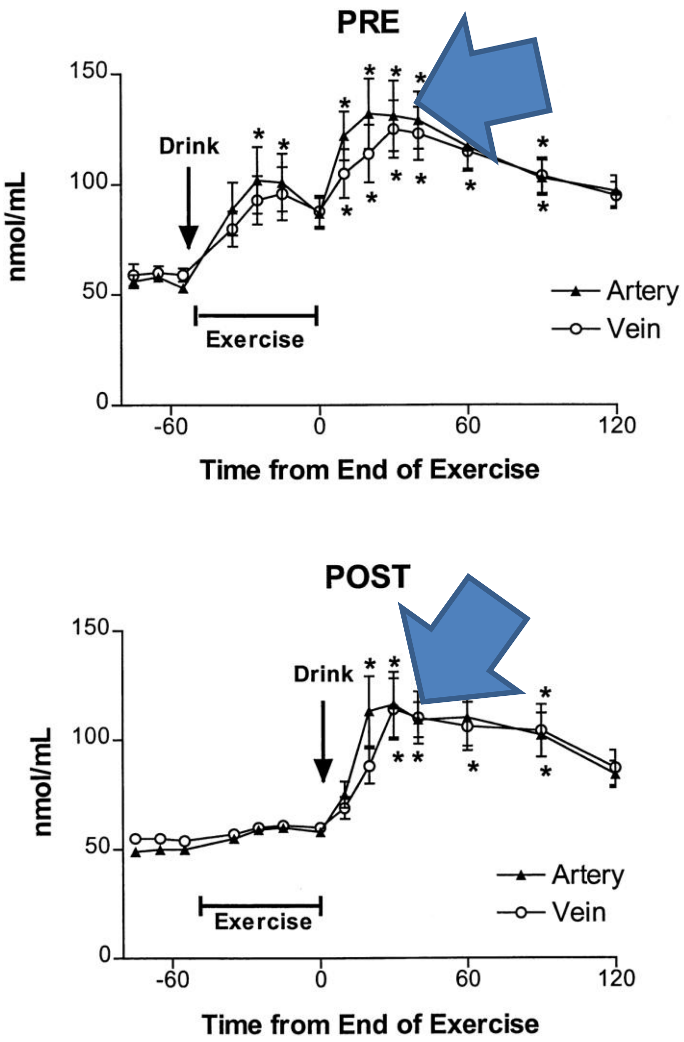
Endocrinology and Metabolism

Arterial and venous phenylalanine concentrations over time for PRE trial (EAC before exercise, top) and POST trial (EAC after exercise, bottom). *Significantly different from resting levels (time −55), $P < 0.05$.



Tipton K D et al. Am J Physiol Endocrinol Metab 2001;281:E197-E206

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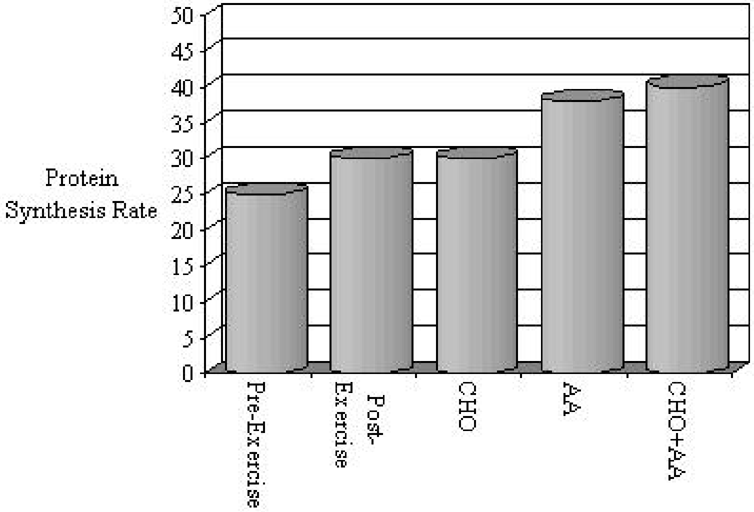
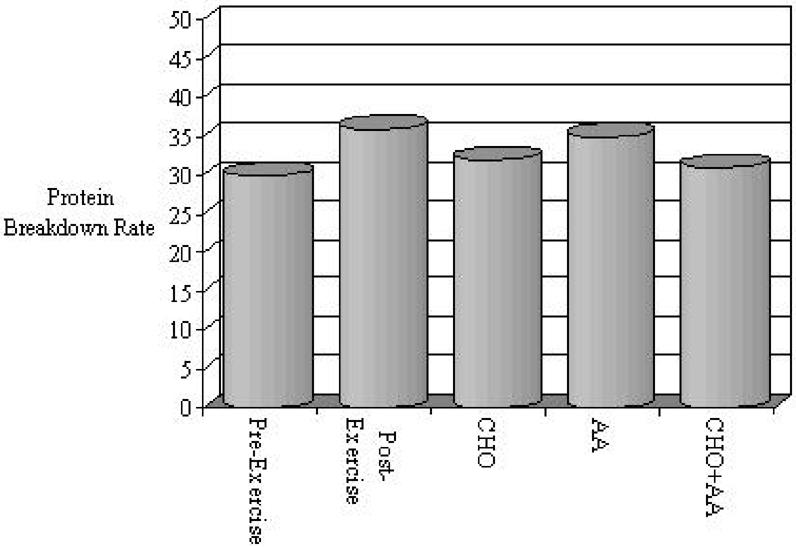
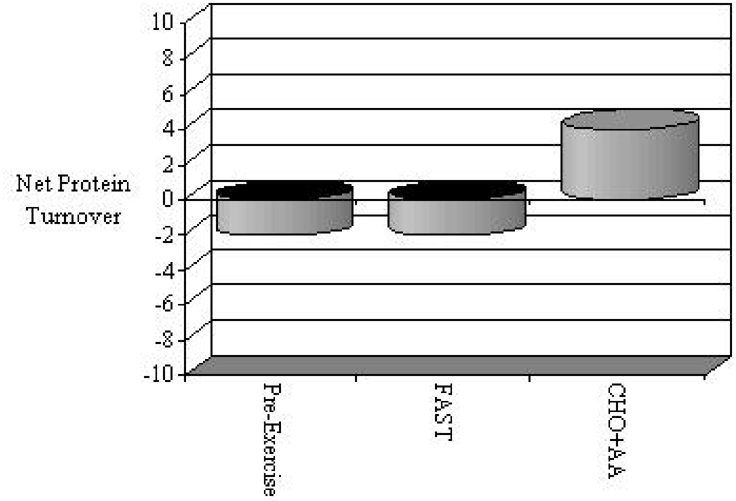
Endocrinology and Metabolism





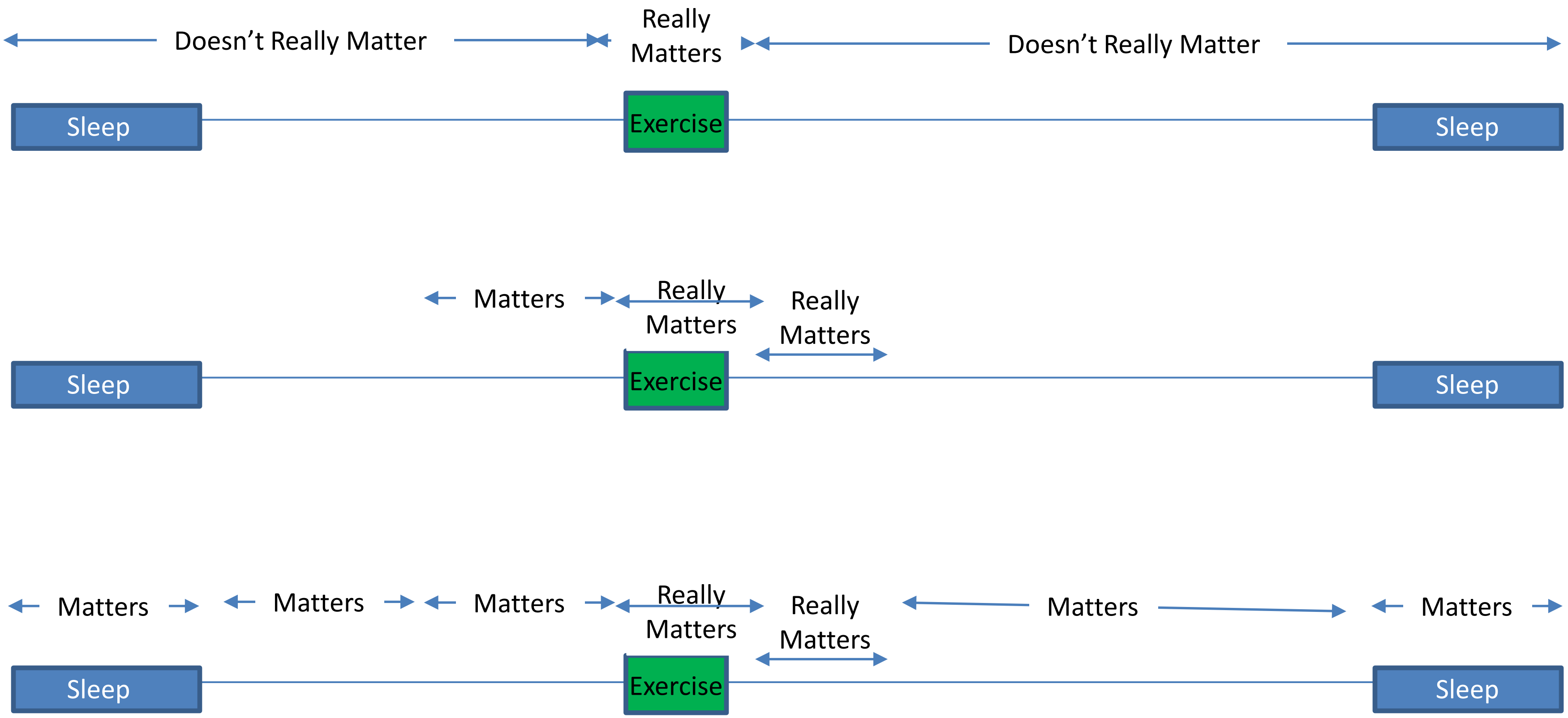


Post Exercise:

Carbohydrate – reduces MPB

Protein (EAA) – heightens MPS

The History of Nutrient Timing



Doesn't Really Matter

Really Matters

Doesn't Really Matter

Sleep

Exercise

Sleep

Matters

Really Matters

Really Matters

Sleep

Exercise

Sleep

Matters

Matters

Matters

Really Matters

Really Matters

Matters

Matters

Sleep

Exercise

Sleep

Nutrient Timing Around Exercise

PRE-EXERCISE

- Glycogen stores are limited and depend largely on the nutritional status and the intensity and training level of the athlete.

- Endogenous glycogen stores during moderate to high intensity levels (65 – 85% VO2max) of exercise may only last from 90 min to 3 h. Exercise intensity, pace and work output decrease as glycogen levels diminish.

- Depletion of glycogen is associated with increased levels of muscle tissue breakdown and suppression of the immune system.

- Maximal endogenous glycogen stores are best promoted by following a high-glycemic, **high-CHO diet (600 – 1000 grams or ~8 – 10 g/kg/d**).

Nutrient Timing Around Exercise

PRE-EXERCISE

- The optimal CHO and PRO content of a pre-exercise meal is dependent upon a number of factors including exercise duration and fitness level, but general guidelines recommend ingestion of **1 – 2 grams CHO/kg and 0.15 –0.25 grams PRO/kg 3 – 4 hours before competition**.

- Pre-exercise ingestion of essential amino acids or PRO alone increases muscle protein synthesis. In addition, **ingesting PRO + CHO pre-exercise has been shown to produce significantly greater levels of muscle protein synthesis**.

- Regular ingestion of various PRO sources in conjunction with CHO stimulates greater increases in strength and favorably impacts body composition when compared to CHO alone.

Nutrient Timing Around Exercise

DURING EXERCISE

- CHO availability during exercise and muscle glycogen levels are major determinants of endurance performance. CHO administration becomes even more important when muscle glycogen levels are low at the onset of exercise

- As exercise duration increases beyond 60 min, exogenous sources of CHO become important to maintain blood glucose and muscle glycogen stores. This CHO source should supply 30 – 60 grams of CHO per hour and can typically be delivered by drinking 1 – 2 cups of a 6 –8% CHO solution (8 – 16 fluid ounces) every 10 – 15 minutes .

- Mixing different forms of CHO has been shown to increase muscle CHO oxidation from 1.0 g CHO/min to levels ranging from 1.2 g – 1.75 g CHO/min; an effect which is associated with an improvement in time trial performance.

Nutrient Timing Around Exercise

DURING EXERCISE

- Glucose, fructose, sucrose and maltodextrin can be used in combination, but large amounts of fructose are not recommended due to the greater likelihood of gastrointestinal problems.
- The addition of PRO to CHO at a ratio of 3 – 4:1 (CHO:PRO) has been shown to increase endurance performance during both acute exercise and subsequent bouts of endurance exercise.
- Ingesting CHO alone, or in combination with PRO, during resistance exercise increases muscle glycogen stores, offsets muscle damage, and facilitates greater training adaptations after acute and prolonged periods of resistance training .

Nutrient Timing Around Exercise

POST EXERCISE

- Post-exercise (within 30 minutes) consumption of CHO at high dosages and at 8 – 10 g CHO/kg/day has been shown to maximally stimulate muscle glycogen re-synthesis.

- Adding PRO to CHO at a ratio of approximately 3: 1 (CHO: PRO) has been shown to stimulate glycogen re-synthesis to a greater extent.

- **Post-exercise ingestion (immediately after through 3 hours post) of amino acids, primarily EAAs, have been shown to stimulate robust increases in muscle PRO synthesis. The addition of CHO may increase PRO synthesis even more, while pre-exercise consumption may result in the best response of all.**

Nutrient Timing Around Exercise

POST EXERCISE

- During prolonged resistance training, post-exercise consumption of CHO + PRO supplements in varying amounts have been shown to stimulate improvements in strength and body composition when compared to control, placebo, or CHO-only conditions.
- The addition of Creatine (0.6-0.1 g Creatine/kg/day) to a CHO + PRO supplement may facilitate even greater adaptations to resistance training.

SLEEP has long been associated with rest, repair, recovery operations

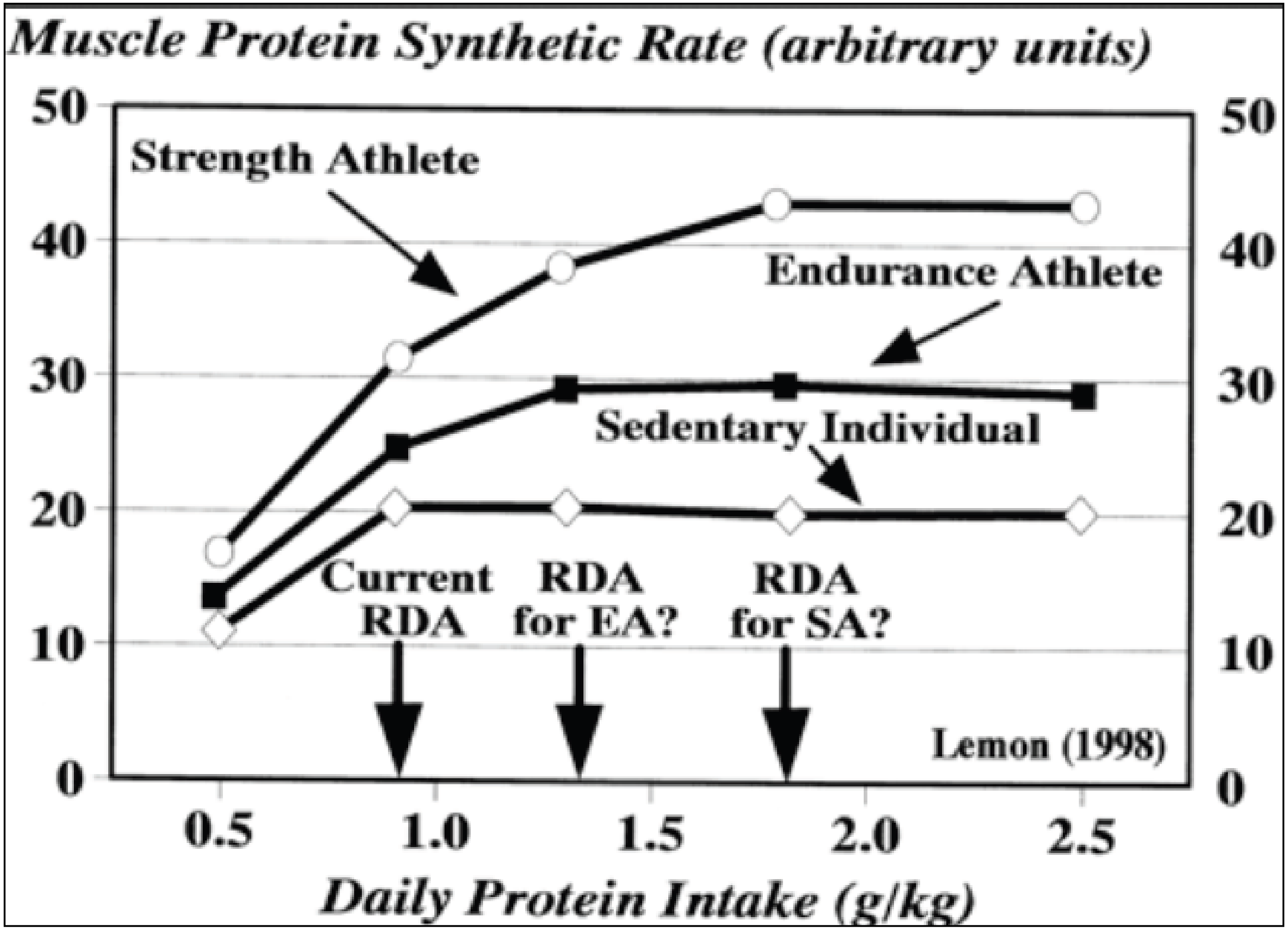
Is SLEEP Nutrition critical for maximal performance adaptation benefit associated with training?

Protein is effectively digested and absorbed and stimulates MPS during sleep (Res et al MSSE 44(8): 1560-9, 2012; Groen et al AJP-EM 302(1): E52-60, 2012)

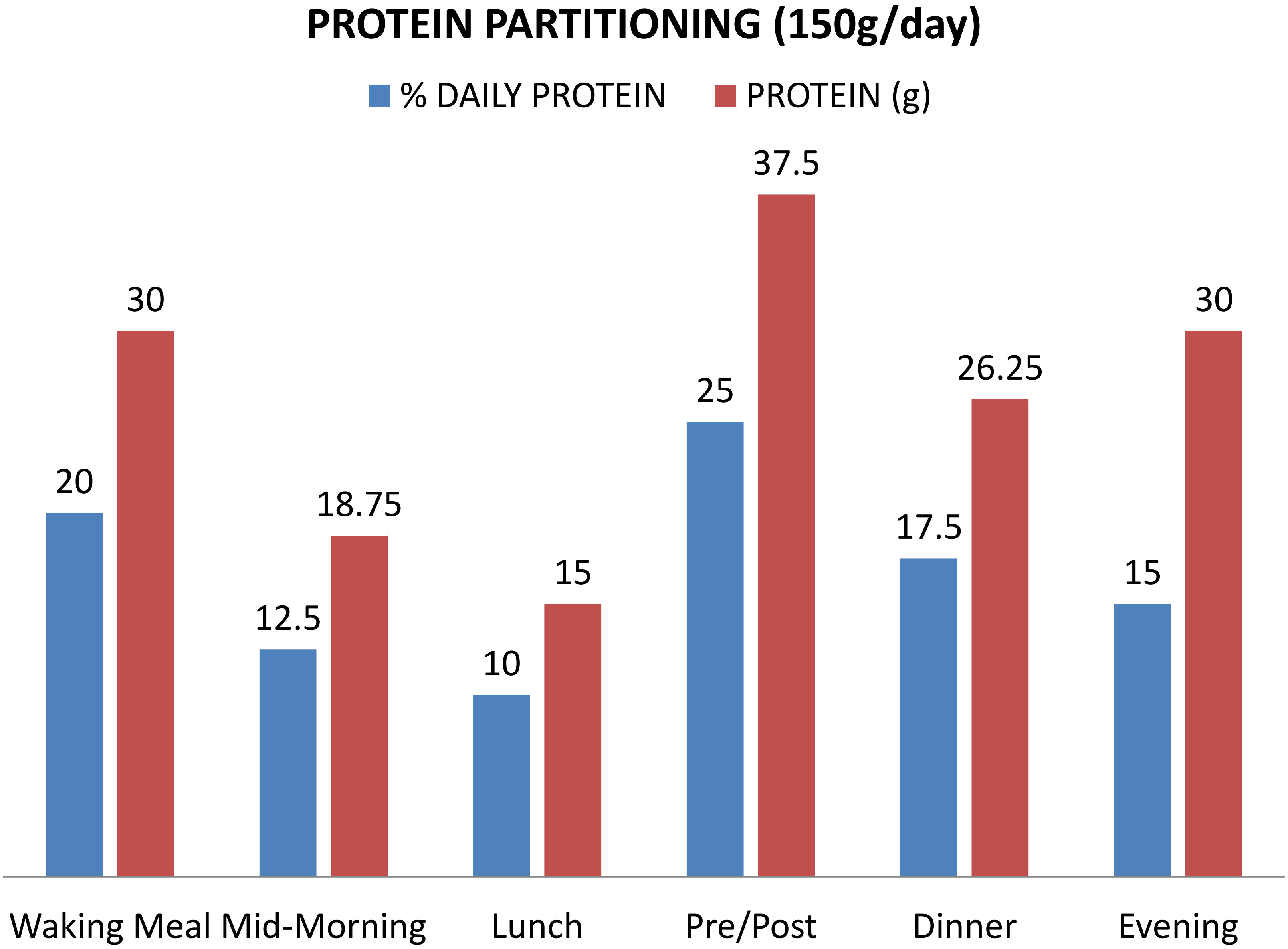
PROTEIN

- HOW MUCH
- TYPES
- TIMING
- COMBINATIONS

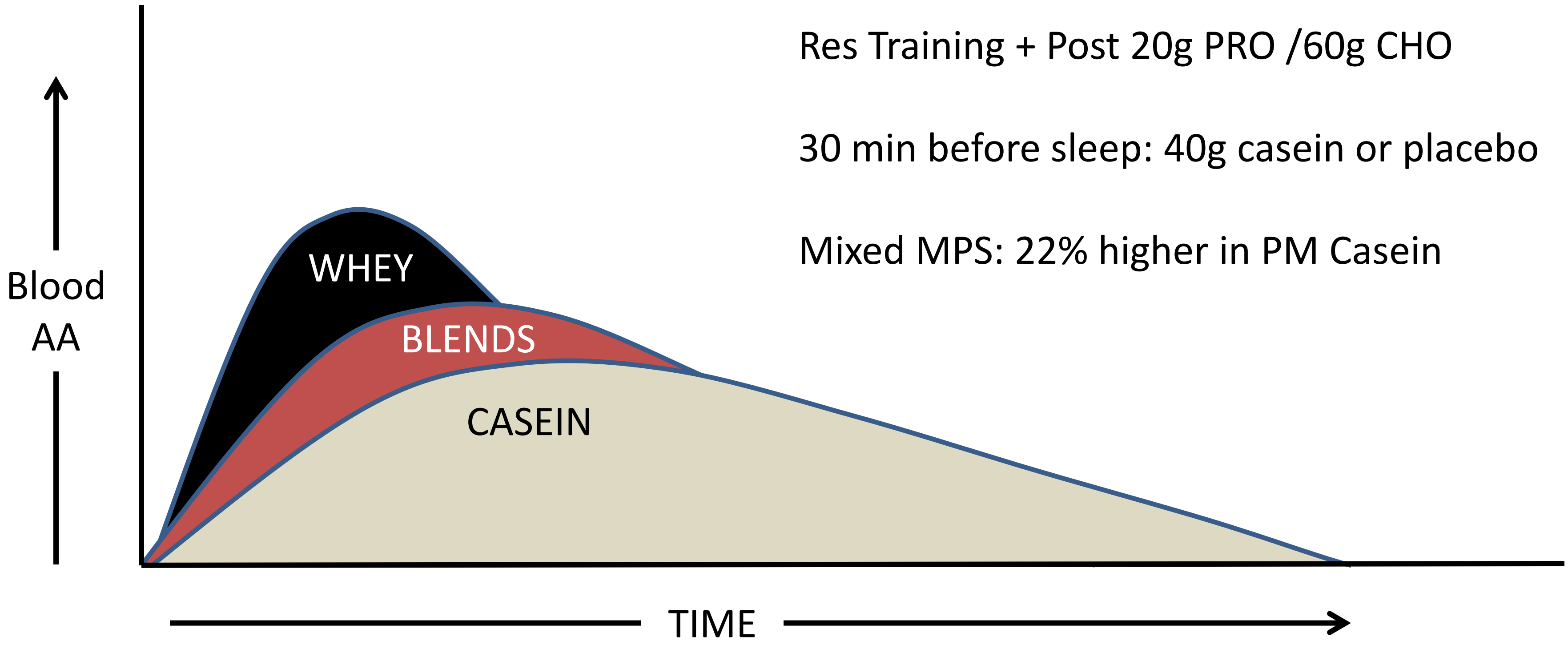
Protein Recommendations



- Not sensitive to timing


PROTEIN PARTITIONING (150g/day)
% DAILY PROTEIN
PROTEIN (g)
20
30
12.5
18.75
10
15
25
37.5
17.5
26.25
15
30
Waking Meal
Mid-Morning
Lunch
Pre/Post
Dinner
Evening

PROTEIN SPEED



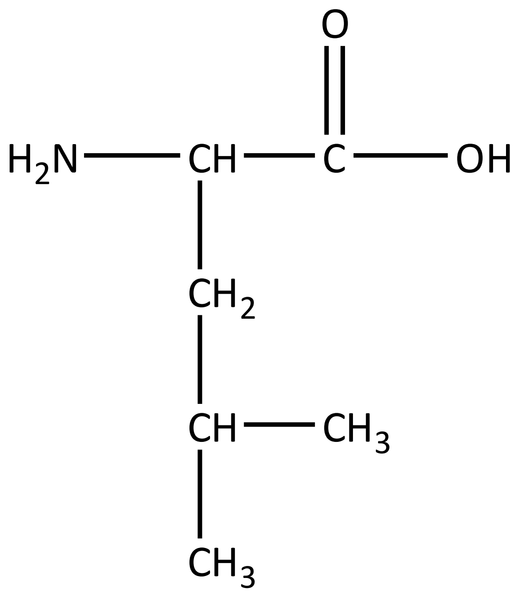
Res et al MSSE 44(8): 1560-9, 2012

Res Training + Post 20g PRO /60g CHO

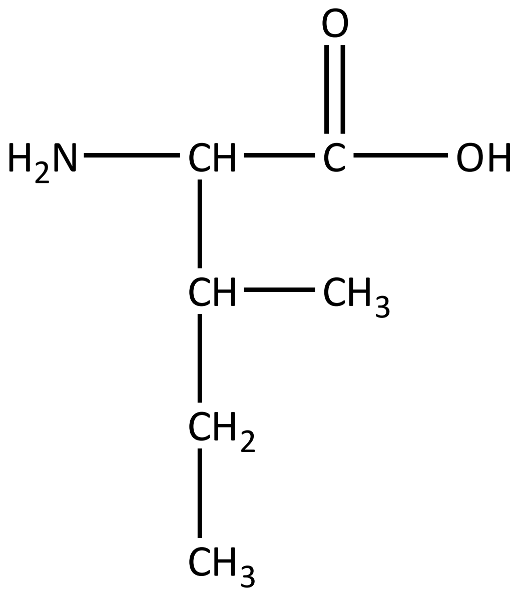
30 min before sleep: 40g casein or placebo

Mixed MPS: 22% higher in PM Casein

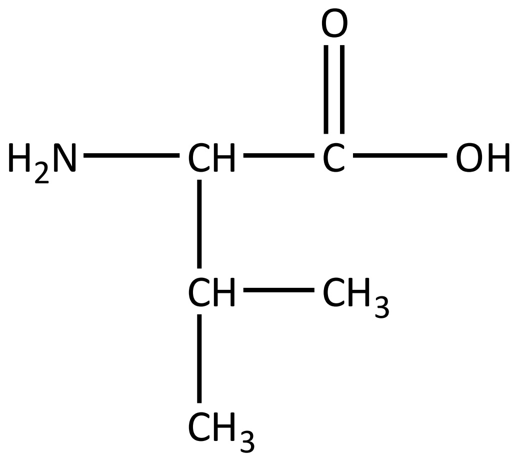
Branched Chain Amino Acids



leucine



isoleucine



valine

Increasing awareness of daily needs (>12 g)
3g noted as key level of leucine to stimulate MPS

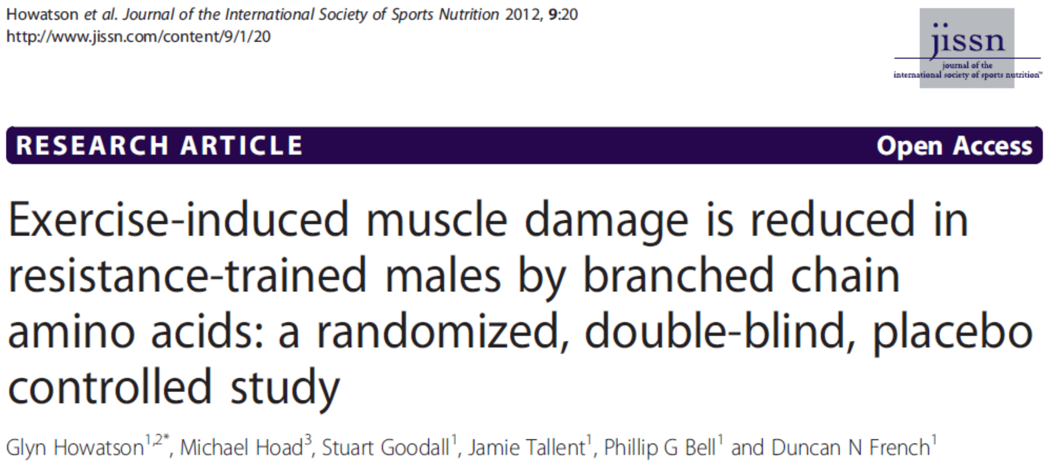
Research

Research has not been supportive of BCAA supplementation improving performance and reducing central fatigue

- incremental cycling effort till exhaustion (Vanier et al, Eur J Appl Physiol Occup Physiol 69(1):26-31, 1994)
- 75% VO_2max in trained cyclists (Blomstrand et al, Acta Physiol Scand 153(2)87-96, 1995)
- Tryptophan or BCAA and 75% max cycling power till exhaustion (van Hall et al, J Physiol 486(Pt3):789-94, 1995)

Research has suggested other effects in athletes
BCAA may limit MPB and promote greater retention or gains of FFM
glutamine reductions (and IL-1) following exhaustive exercise (Candeloro et al Minerva Endocrinol 1995, 20(4):217-23)

- BCAA reduced plasma markers of tissue damage following endurance exercise (Coombes et al, J Sport Med Phys Fitn 40(3):240-6, 2000)



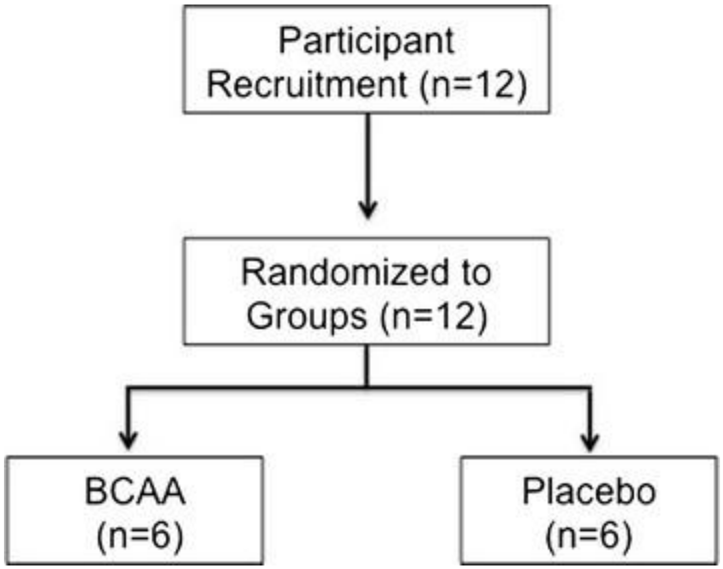
Howatson *et al. Journal of the International Society of Sports Nutrition* 2012, **9**:20
http://www.jissn.com/content/9/1/20

jissn
journal of the international society of sports nutrition

RESEARCH ARTICLE **Open Access**

Exercise-induced muscle damage is reduced in resistance-trained males by branched chain amino acids: a randomized, double-blind, placebo controlled study

Glyn Howatson[1,2*], Michael Hoad[3], Stuart Goodall[1], Jamie Tallent[1], Phillip G Bell[1] and Duncan N French[1]

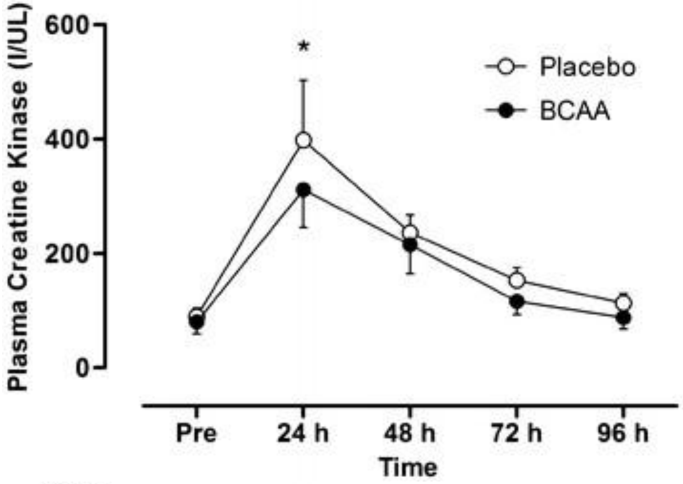


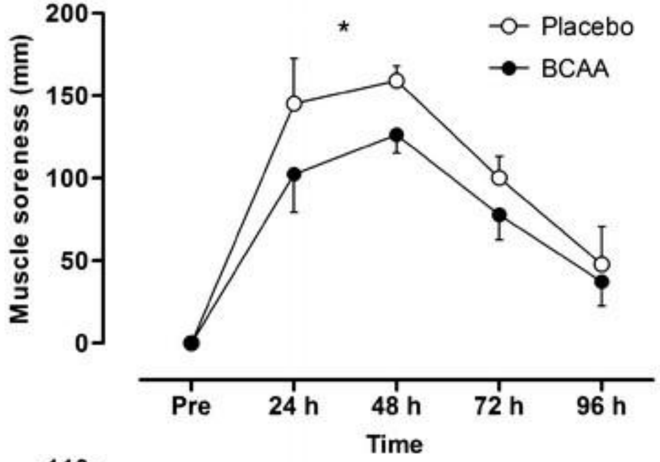
Participant Recruitment (n=12)

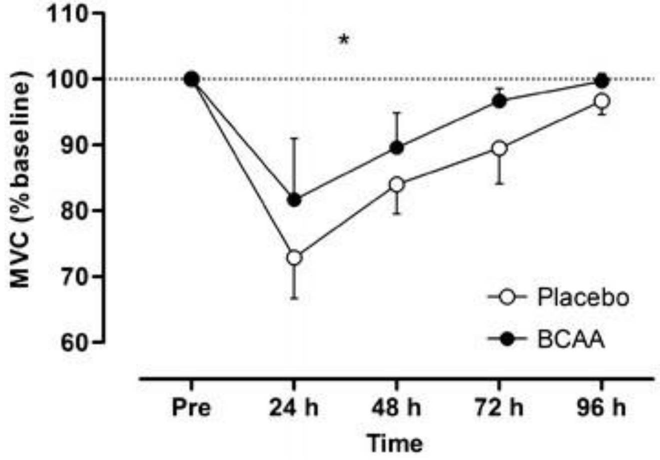
Randomized to Groups (n=12)

BCAA (n=6)

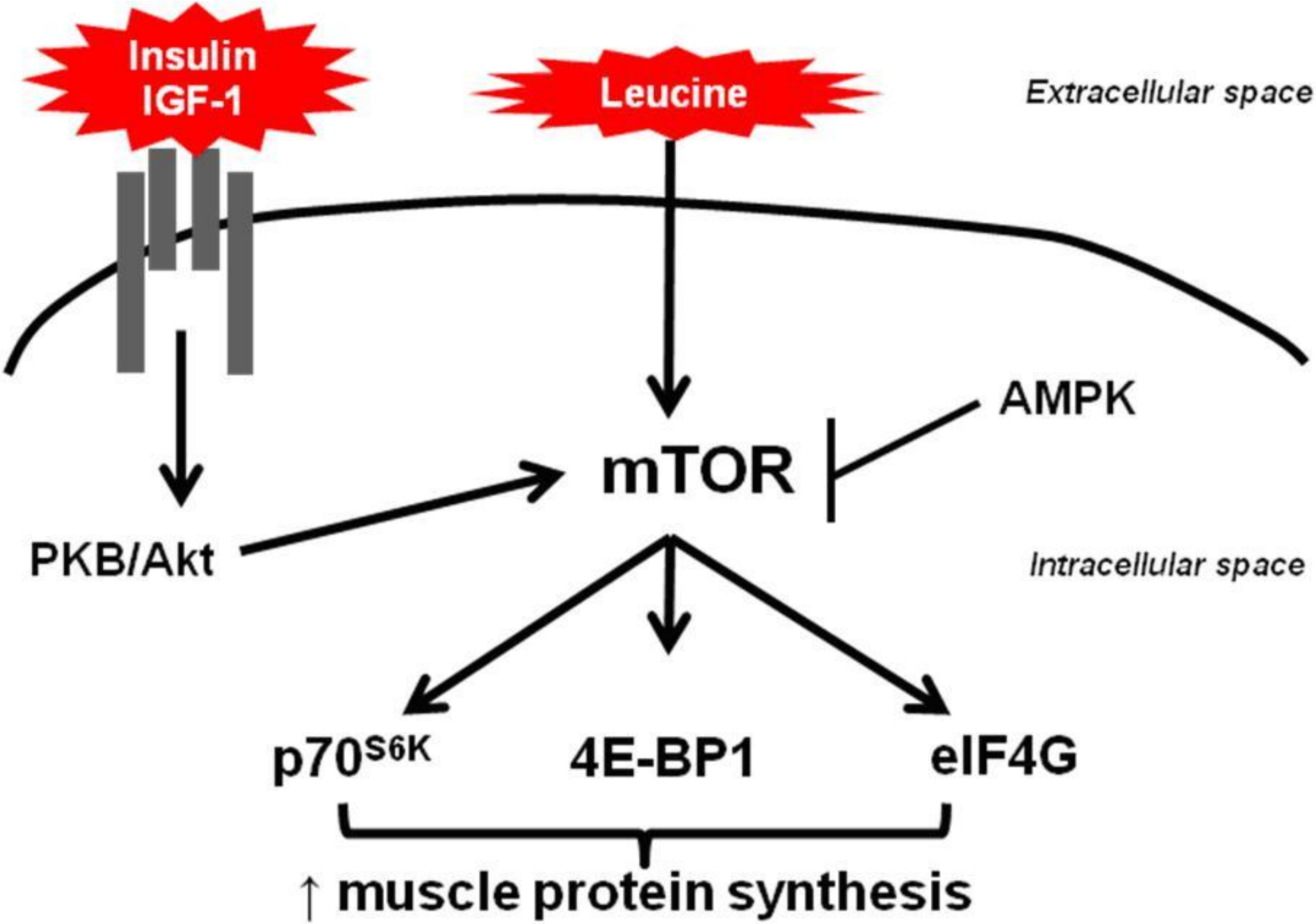
Placebo (n=6)







Supplement: 20 g – 2:1:1 daily for 7 days
Training session with additional 20 g pre/post
Measures for ensuing 4 days (with supplementation)


Insulin
IGF-1
Leucine
Extracellular space
AMPK
mTOR
PKB/Akt
Intracellular space
p70^{S6K}
4E-BP1
eIF4G
↑ muscle protein synthesis

Leucine

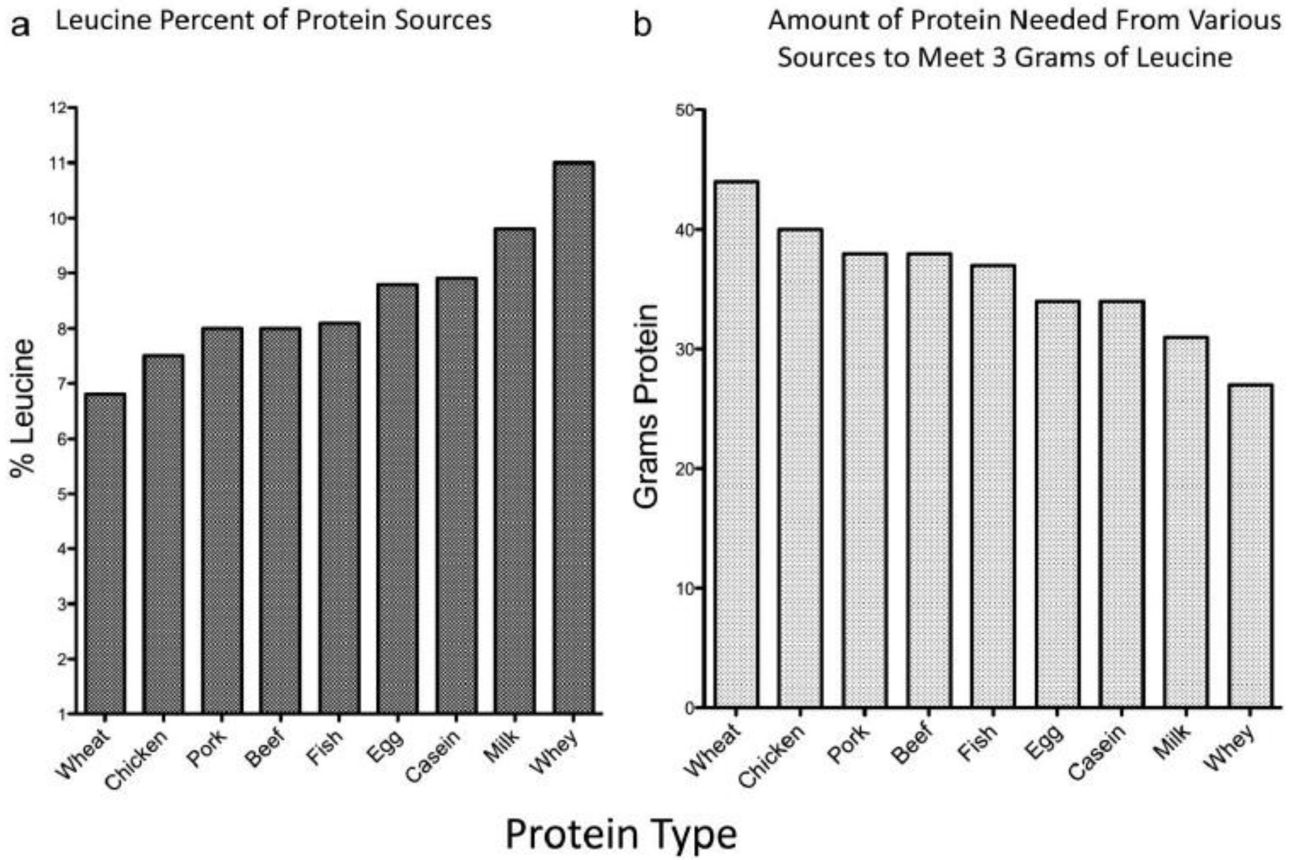


Figure. (a) Leucine percent of protein sources. (b) Amount of protein needed from various sources to meet 3 g of leucine.

Wilson et al, Strength & Conditioning Journal 34(4): 34-48, 2012

PeptoPro

- Casein hydrolysate
- Short-chain peptide delivery system
- Designed for faster absorption
- ~85% protein - rich in small peptides
  - ~7.5% is free amino acids
  - ~8.5% is dipeptides
  - ~39% is tripeptides.

PeptoPro

When do you have to take PeptoPro®?

- PeptoPro® can be taken prior to exercise (e.g. as 350-500 ml of a 1% protein drink) to stimulate muscle protein synthesis.
- PeptoPro® can be taken during exercise (e.g. regularly sipping a 1-2% protein drink) to reduce the muscle protein breakdown that normally occurs during exercise, and to increase its synthesis.
- PeptoPro® can be taken directly after exercise (e.g. as 350-500 ml of a 2-4% protein drink) to rapidly restore muscle glycogen stores as well as enhance muscle protein synthesis.

CARBOHYDRATES

- HOW MUCH
- TYPES
- TIMING
- COMBINATIONS

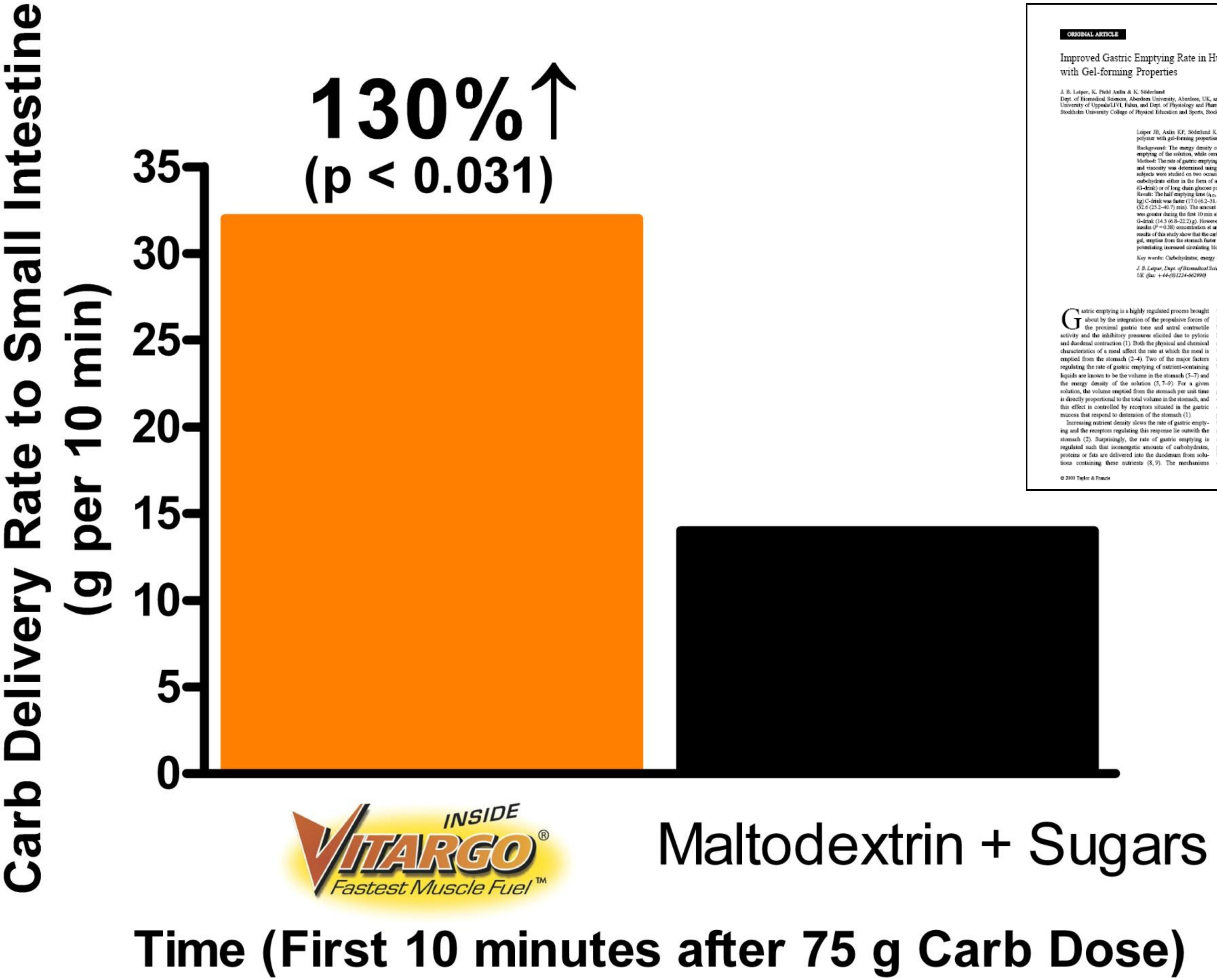
Relative Properties of Different Carbohydrates

Carbohydrate Type	Molecular Size*	Digestibility/ Absorption**	Glycemic Effect*	Insulinemic Effect*
Glucose (Dextrose)	Very Small	Fast	High	High
Fructose	Very Small	Very Slow	Very Low	Very Low
Sucrose	Very Small	Moderate	Moderate	Moderate
Corn Syrup	Medium	Fast	High	High
High Fructose Corn Syrup (HFCS)***	Medium	Moderate	Moderate	Moderate
Maltodextrin	Medium	Fast	High	High
Waxy Maize Starch (WMS)	Large	Slow	Low	Low
Vitargo®	Very Large	Very Fast	Very High	Very High
Amylose	Large	Very Slow	Very Low	Very Low

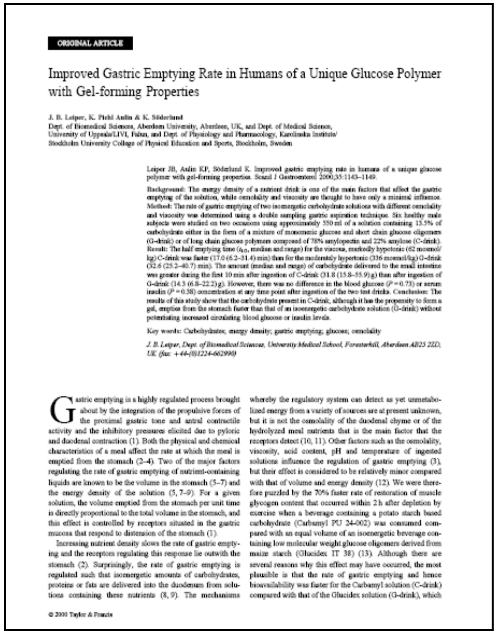
* Due to limitations in research data availability and industry information some of the values on this table are based on estimations. Also, these properties are based on independent effect. Properties can be modified when integrated into more complex food and supplement formulations.

**Assumes similar absorption rates of post-digestion glucose. Fructose will be absorbed by a slower process than glucose.

***Assumes commonly used HFCS-55 (55% fructose)



Refererence: Leiper *et al. Scand J Gastroenterol*, 2000.



ORIGINAL ARTICLE

Improved Gastric Emptying Rate in Humans of a Unique Glucose Polymer with Gel-forming Properties

J. B. Leiper, K. Piehl Aulin & K. Söderlund
Dept. of Biomedical Sciences, Aberdeen University, Aberdeen, UK, and Dept. of Medical Science, University of Uppsala/LIVI, Falun, and Dept. of Physiology and Pharmacology, Karolinska Institute/ Stockholm University College of Physical Education and Sports, Stockholm, Sweden

Leiper JB, Aulin KP, Söderlund K. Improved gastric emptying rate in humans of a unique glucose polymer with gel-forming properties. Scand J Gastroenterol 2000;35:1143–1149.

Background: The energy density of a nutrient drink is one of the main factors that affect the gastric emptying of the solution, while osmolality and viscosity are thought to have only a minimal influence. Method: The rate of gastric emptying of two isoenergetic carbohydrate solutions with different osmolality and viscosity was determined using a double sampling gastric aspiration technique. Six healthy male subjects were studied on two occasions using approximately 550 ml of a solution containing 13.5% of carbohydrate either in the form of a mixture of monomeric glucose and short chain glucose oligomers (G-drink) or of long chain glucose polymers composed of 78% amylopectin and 22% amylose (C-drink). Result: The half emptying time ($t_{1/2}$, median and range) for the viscous, markedly hypotonic (62 mosmol/kg) C-drink was faster (17.0 (6.2–31.4) min) than for the moderately hypertonic (336 mosmol/kg) G-drink (32.6 (25.2–40.7) min). The amount (median and range) of carbohydrate delivered to the small intestine was greater during the first 10 min after ingestion of C-drink (31.8 (15.8–55.9) g) than after ingestion of G-drink (14.3 (6.8–22.2) g). However, there was no difference in the blood glucose ($P = 0.73$) or serum insulin ($P = 0.38$) concentration at any time point after ingestion of the two test drinks. Conclusion: The results of this study show that the carbohydrate present in C-drink, although it has the propensity to form a gel, empties from the stomach faster than that of an isoenergetic carbohydrate solution (G-drink) without potentiating increased circulating blood glucose or insulin levels.

Key words: Carbohydrates; energy density; gastric emptying; glucose; osmolality

J. B. Leiper, Dept. of Biomedical Sciences, University Medical School, Foresterhill, Aberdeen AB25 2ZD, UK (fax: +44-(0)1224-662990)

Gastric emptying is a highly regulated process brought about by the integration of the propulsive forces of the proximal gastric tone and antral contractile activity and the inhibitory pressures elicited due to pyloric and duodenal contraction (1). Both the physical and chemical characteristics of a meal affect the rate at which the meal is emptied from the stomach (2–4). Two of the major factors regulating the rate of gastric emptying of nutrient-containing liquids are known to be the volume in the stomach (5–7) and the energy density of the solution (5, 7–9). For a given solution, the volume emptied from the stomach per unit time is directly proportional to the total volume in the stomach, and this effect is controlled by receptors situated in the gastric mucosa that respond to distension of the stomach (1).

Increasing nutrient density slows the rate of gastric emptying and the receptors regulating this response lie outwith the stomach (2). Surprisingly, the rate of gastric emptying is regulated such that isoenergetic amounts of carbohydrates, proteins or fats are delivered into the duodenum from solutions containing these nutrients (8, 9). The mechanisms whereby the regulatory system can detect as yet unmetabolized energy from a variety of sources are at present unknown, but it is not the osmolality of the duodenal chyme or of the hydrolyzed meal nutrients that is the main factor that the receptors detect (10, 11). Other factors such as the osmolality, viscosity, acid content, pH and temperature of ingested solutions influence the regulation of gastric emptying (3), but their effect is considered to be relatively minor compared with that of volume and energy density (12). We were therefore puzzled by the 70% faster rate of restoration of muscle glycogen content that occurred within 2 h after depletion by exercise when a beverage containing a potato starch based carbohydrate (Carbamyl PU 24-002) was consumed compared with an equal volume of an isoenergetic beverage containing low molecular weight glucose oligomers derived from maize starch (Glucidex IT 38) (13). Although there are several reasons why this effect may have occurred, the most plausible is that the rate of gastric emptying and hence bioavailability was faster for the Carbamyl solution (C-drink) compared with that of the Glucidex solution (G-drink), which

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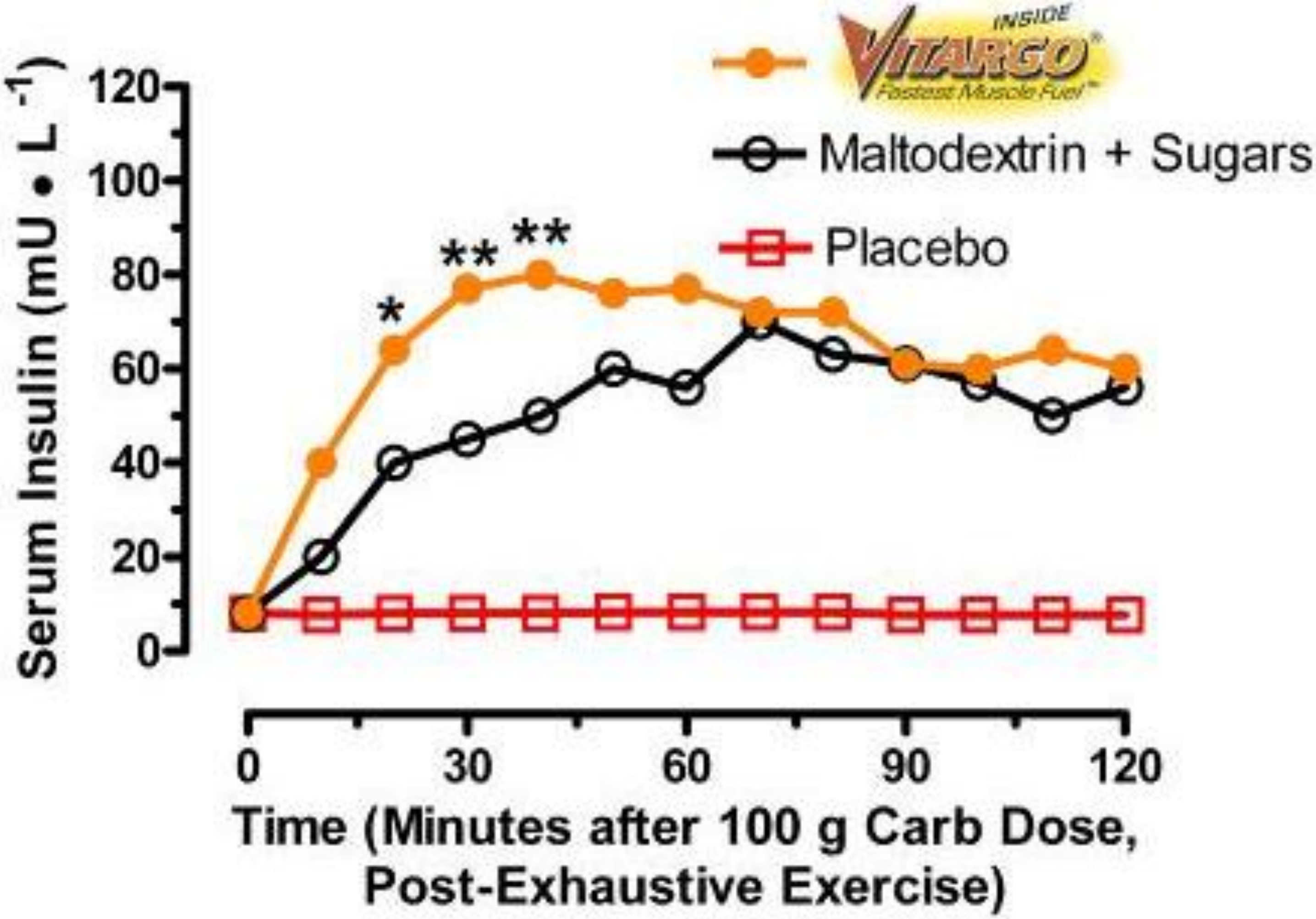

Refererence: Stephens *et al. J Sports Sci*, 2008.

Journal of Sports Sciences, January 15th 2008; 26(2): 149–154

Post-exercise ingestion of a unique, high molecular weight glucose polymer solution improves performance during a subsequent bout of cycling exercise

FRANCIS B. STEPHENS, MARC ROIG, GERALD ARMSTRONG, &
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(Accepted 24 March 2007)

Abstract

The aim of the present study was to determine the effect of post-exercise ingestion of a unique, high molecular weight glucose polymer solution, known to augment gastric emptying and post-exercise muscle glycogen re-synthesis, on performance during a subsequent bout of intense exercise. On three randomized visits, eight healthy men cycled to exhaustion at 73.0% ($s = 1.3$) maximal oxygen uptake (90 min, $s = 15$). Immediately after this, participants consumed a one-litre solution containing sugar-free flavoured water (control), 100 g of a low molecular weight glucose polymer or 100 g of a very high molecular weight glucose polymer, and rested on a bed for 2 h. After recovery, a 15-min time-trial was performed on a cycle ergometer, during which work output was determined. Post-exercise ingestion of the very high molecular weight glucose polymer solution resulted in faster and greater increases in blood glucose ($P < 0.001$) and serum insulin ($P < 0.01$) concentrations than the low molecular weight glucose polymer solution, and greater work output during the 15-min time-trial (164.1 kJ, $s = 21.1$) than both the sugar-free flavoured water (137.5 kJ, $s = 24.2$; $P < 0.05$) and the low molecular weight glucose polymer (149.4 kJ, $s = 21.8$; $P < 0.05$) solutions. These findings could be of practical importance for athletes wishing to optimize performance by facilitating rapid re-synthesis of the muscle glycogen store during recovery following prolonged sub-maximal exercise.

Keywords: *Gastric emptying, skeletal muscle glycogen, sub-maximal exercise*

Introduction

Muscle glycogen is recognized as the major fuel supporting adenosine triphosphate (ATP) homeostasis during sustained moderate-to-intense exercise, with the rate of glycogen utilization increasing with the intensity of exercise performed (Bergstrom, Hermansen, Hultman, & Saltin, 1967; Bergstrom & Hultman, 1966, 1967a; Hultman, Bergstrom, & Anderson, 1967). The depletion of muscle glycogen during exercise is associated with an accelerated rate of muscle phosphocreatine degradation, adenine nucleotide loss (Broberg & Sahlin, 1989), and muscle fatigue (Bergstrom & Hultman, 1966; Hultman *et al.*, 1967), most probably due to the inability of muscle to maintain ATP production at the required rate. Thus, high pre-exercise muscle (and liver) glycogen concentrations are believed to be essential for optimal endurance exercise performance (Bergstrom *et al.*, 1967), and the rapid re-synthesis of the muscle glycogen store is, therefore, of crucial importance during recovery for individuals who take part in training sessions or competitions where prolonged sub-maximal exercise or several periods of sub-maximal or intense exercise are performed in a single day.

Limiting factors to post-exercise muscle glycogen re-synthesis following carbohydrate feeding include the amount, timing, and form of carbohydrate administered, the rate of gastric emptying and intestinal absorption of the ingested carbohydrate, glucose storage and output by the liver, and muscle glucose transport and oxidation (for a review, see Jentjens & Jeukendrup, 2003). Studies in which glucose has been intravenously infused immediately following glycogen-depleting exercise have reported two- to three-fold greater rates of glycogen re-synthesis compared with post-exercise carbohydrate feeding [30–40 vs.

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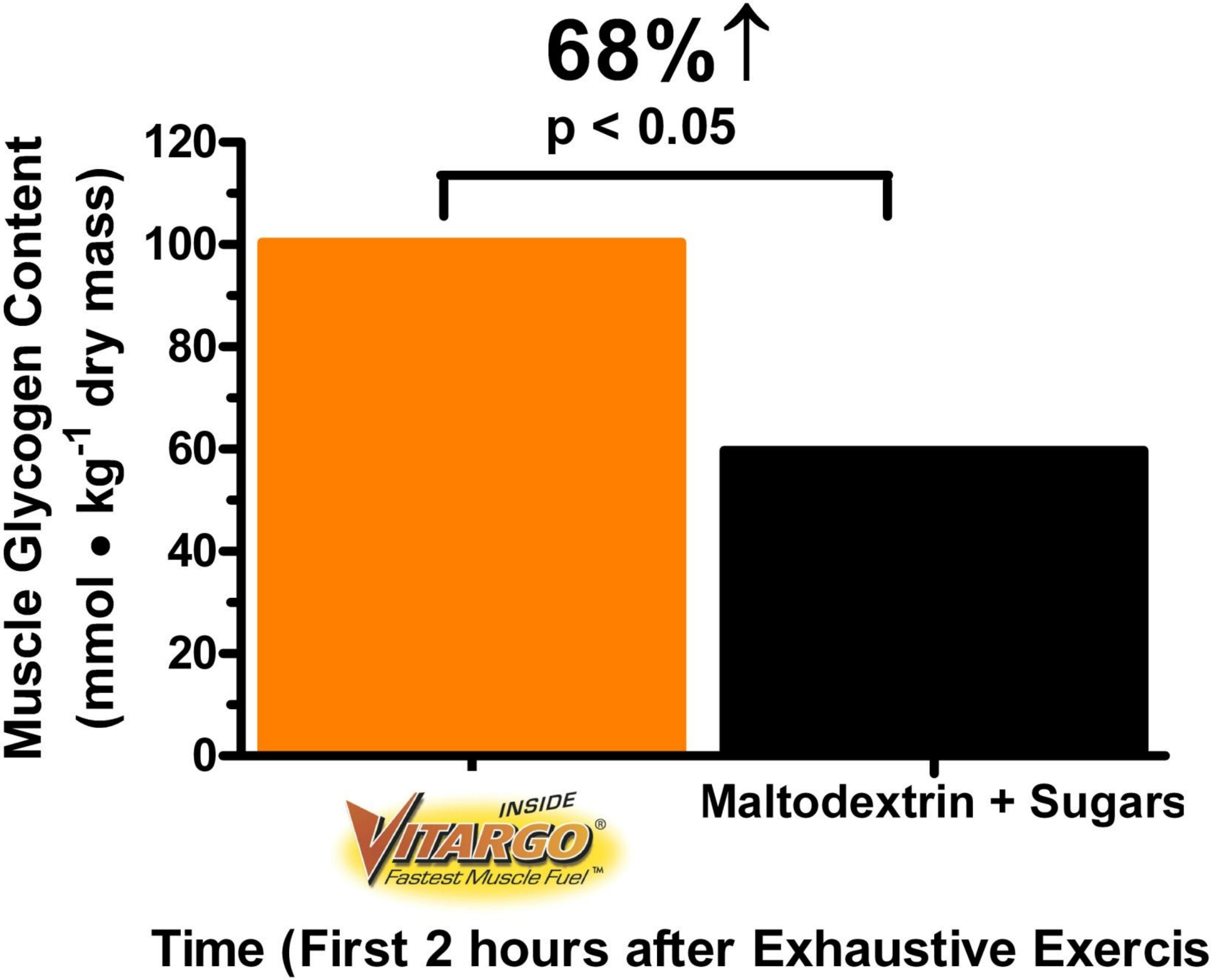
DOI: 10.1080/02640410701361548



Refererence: Aulin *et al.* Eur J Appl Physiol, 2000.

Eur J Appl Physiol (2000) 81: 346–351

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ORIGINAL ARTICLE

K. Piehl Aulin · K. Söderlund · E. Hultman

Muscle glycogen resynthesis rate in humans after supplementation of drinks containing carbohydrates with low and high molecular masses

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Abstract The rate of muscle glycogen synthesis during 2 and 4 h of recovery after depletion by exercise was studied using two energy equivalent carbohydrate drinks, one containing a polyglucoside with a mean molecular mass of 500 000–700 000 (C drink), and one containing monomers and oligomers of glucose with a mean molecular mass of approximately 500 (G drink). The osmolality was 84 and 350 mosmol · l^{-1}, respectively. A group of 13 healthy well-trained men ingested the drinks after glycogen depleting exercise, one drink at each test occasion. The total amount of carbohydrates consumed was 300 g (4.2 g · kg^{-1}) body mass given as 75 g in 500 ml water immediately after exercise and again 30, 60 ad 90-min post exercise. Blood glucose and insulin concentrations were recorded at rest and every 30 min throughout the 4-h recovery period. Muscle biopsies were obtained at the end of exercise and after 2 and 4 h of recovery. Mean muscle glycogen contents after exercise were 52.9 (SD 27.4) mmol glycosyl units · kg^{-1} (dry mass) in the C group and 58.3 (SD 35.4) mmol glycosyl units · kg^{-1} (dry mass) in the G group. Mean glycogen synthesis rate was significantly higher during the initial 2 h for the C drink compared to the G drink: 50.2 (SD 13.7) mmol · kg^{-1} (dry mass) · h^{-1} in the C group and 29.9 (SD 12.5) mmol · kg^{-1} (dry mass) · h^{-1} in the G group. During the last 2 h the mean synthesis rate was 18.8 (SD 33.3) and 23.3 (SD 22.4) mmol · kg^{-1} (dry mass) · h^{-1} in the C and G group, respectively (n.s.). Mean blood glucose and insulin concentrations did not differ between the two drinks. Our data indicted that the osmolality of the carbohydrate drink may influence the rate of resynthesis of glycogen in muscle after its depletion by exercise.

Key words Carbohydrate · Osmolality · Glycogen · Insulin · Glucose

Introduction

It has generally been accepted that prolonged submaximal exercise is limited by the availability of muscle and liver glycogen stores and that these stores increase when carbohydrate intake is high (Bergström and Hultman 1967; Bergström et al. 1967). It has also been shown that the rate of glycogen synthesis is highest in muscles in which the glycogen stores have been depleted by exercise (Bergström and Hultman 1966).

The rate of glycogen synthesis following exercise is of importance for athletes during training sessions with repeated periods of heavy or submaximal exercise as well as during competition especially when several periods of intense exercise are performed. Synthesis of muscle glycogen from ingested carbohydrates is dependant on the transport of glucose across the intestinal mucosa and the muscle cell membrane and on the enzymes responsible for glycogen phosphorylation and synthesis.

Blood glucose concentrations are influenced by the flux of glucose from the stomach, via the intestine and into the blood. It has been shown that the osmolality of an ingested solution can interfere with the emptying rate from the stomach (Hunt et al. 1985; Vist and Maughan 1995). Thus a high osmolality may delay gastric emptying which could delay the release of glucose from the intestine. It has also been shown that the rate of synthesis of muscle glycogen is highest during the first 2 h after exercise (Kiens et al. 1990). In the present study, the aim was to compare the rate of synthesis of muscle glycogen during the first 2 and 4 h after ingestion of two

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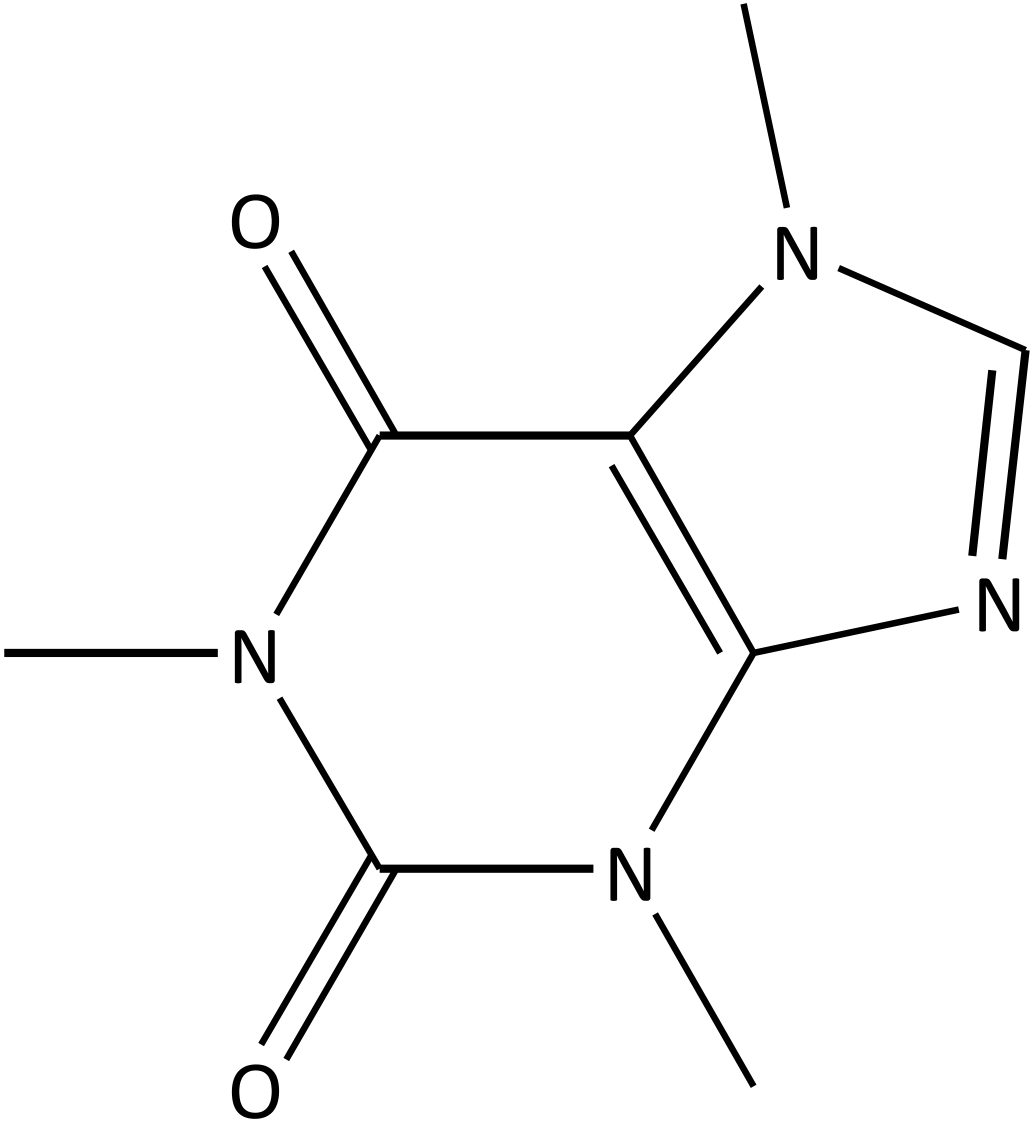
Glycemic Index and Load Levels

Level	Glycemic Index	Glycemic Load	Glycemic Load/Day
Low	55 or less	10 or less	**Less than 80**
Medium	56 to 69	11 to 19	**80 to 120**
High	**70 or more**	**20 or more**	**More than 120**

Glycemic Index and Load Levels

Food	Glycemic Index	Glycemic Load	Food	Glycemic Index	Glycemic Load
All-bran cereal	42	8	Peanuts	14	1
Apple juice	40	11	Pears	38	4
Apples	38	6	Pineapple	59	7
Bananas	52	12	Pinto beans	39	10
Beets	64	5	Popcorn	72	8
Buckwheat	54	16	Potatoes (New)	57	12
Cantaloupe	65	4	Potatoes (Russet, Baked)	85	26
Carrots	47	3	Rice, White	64	23
Cherrios Cereal	74	15	Rice, Wild	57	18
Corn Flakes Cereal	81	21	Sourdough wheat bread	54	15
Couscous	65	23	Spaghetti	42	20
Fettucine	40	18	Strawberries	40	1
Grapes	46	8	Sucrose (table sugar)	68	7
Green peas	48	3	Shredded Wheat Cereal		
Kidney beans	28	7	Sweet corn	54	9
Life cereal	66	16	Sweet potatoes	61	17
Linguine	52	23	Watermelon	72	4
Macaroni	47	23	Whole wheat flour bread	71	9



caffeine

CAFFEINE PRE-EXERCISE

- Caffeine is effective for enhancing sport performance in trained athletes when consumed in low-to-moderate dosages (~3-6 mg/kg).

- Caffeine exerts a greater ergogenic effect when consumed in an anhydrous state

- Caffeine has been shown to enhance vigilance during bouts of extended exhaustive exercise, as well as periods of sustained sleep deprivation.

- Caffeine is ergogenic for sustained maximal endurance exercise and has been shown to be highly effective for time-trial performance.

- Caffeine supplementation is beneficial for high-intensity exercise.

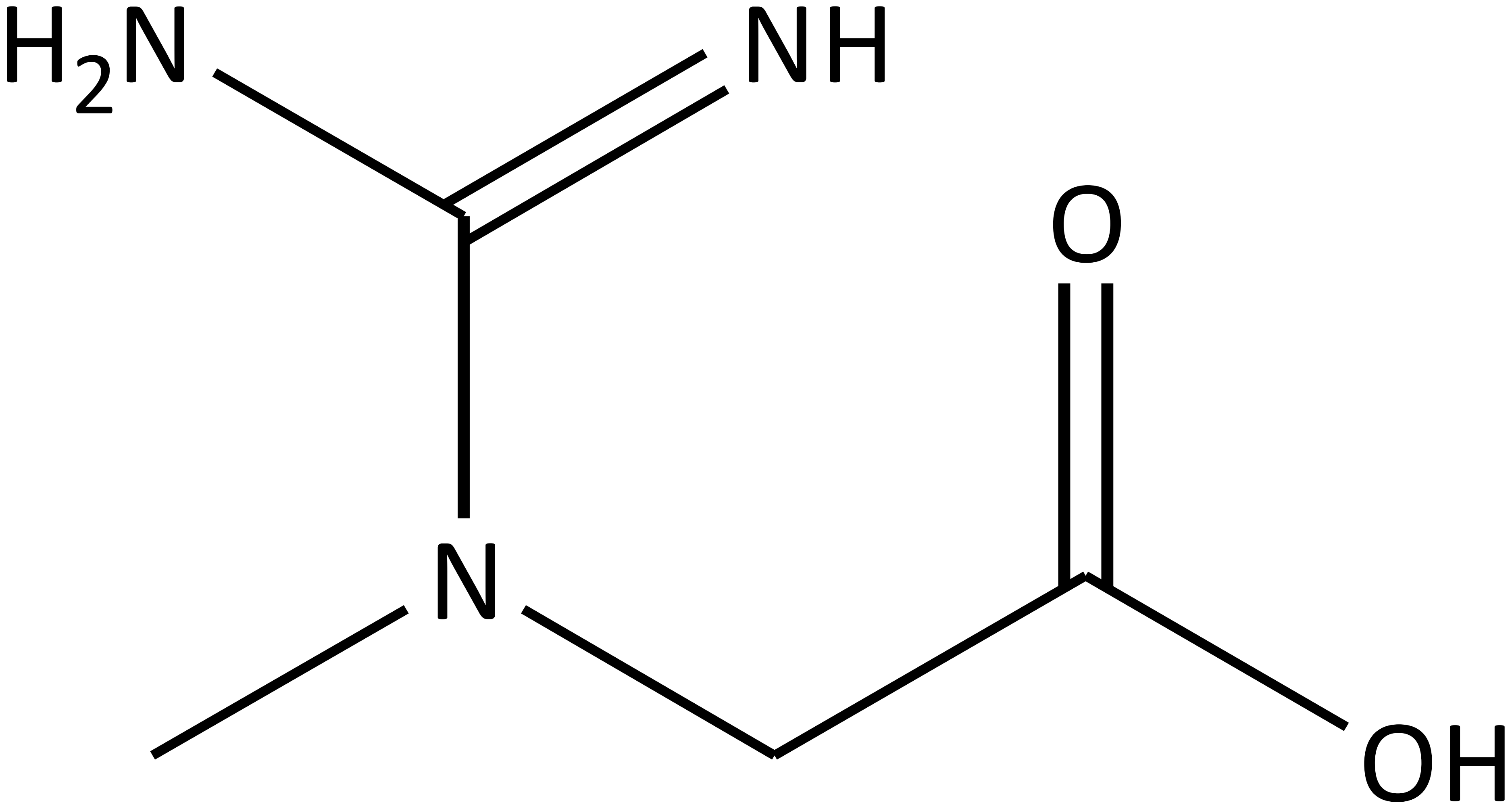
- The literature is equivocal on caffeine’s benefit in strength-power performance.

CAFFEINE POST-EXERCISE

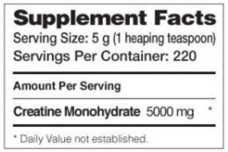
- Some support that caffeine post-training supports glycogen recovery

GENERAL

- The scientific literature does not support caffeine induced dieresis during exercise or any harmful change in fluid balance that would negatively affect performance



creatine



Supplement Facts

Serving Size: 5 g (1 heaping teaspoon)

Servings Per Container: 220

Amount Per Serving	
Creatine Monohydrate 5000 mg	*

* Daily Value not established.

Creatine

- Good evidence that creatine supplementation increases muscle size, and body weight and lean body mass and strength in adaptive scenarios

- Creatine most applied to sprint & high power bouts

- Loading dose 20-25 g/d (5-7 days) then maintenance 5g/d based upon research (Hultman *et al,* J Appl Physiol 81(1)232-7, 1996)

- Increase muscle creatine up to 20% with either loading/maintenance or just maintenance dosing (Hultman et al, J Appl Physiol 81(1)232-7, 1996; Volek et al, MSSE 31(8):1147-56,1999)

    - Carnivorus diet already has 1-3 g/d

- Athletes need to experiment (especially sprinters & volleyball, baseball, volleyball and football players

- Generally regarded as safe via retrospective studies. Found to not change cardiac S/F (Wildman *et al* J Nutraceuticals Funct Foods 2006)

- Recommended 0.06 - 0.08 g/kg BW -> 5-6 g/day (Me)

- Split dosing is now recommended

NUTRIENT TIMING
for
Optimal Performance and Training Adaptation

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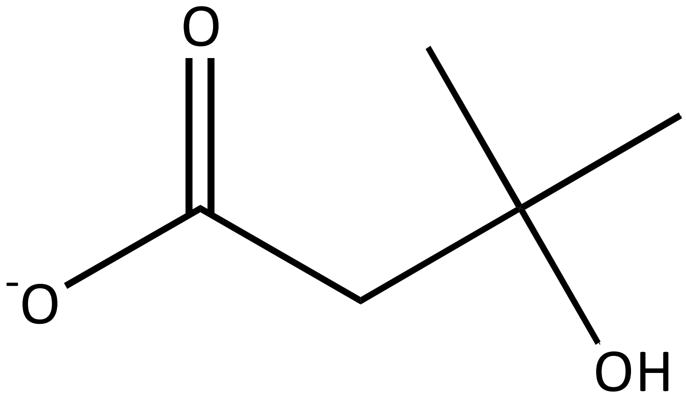
HMB



b-hydroxy-b-methylbutyrate

- Leucine derivative
- Supplements provided at 1-3 gram/day
- Can enhance LBM and strength
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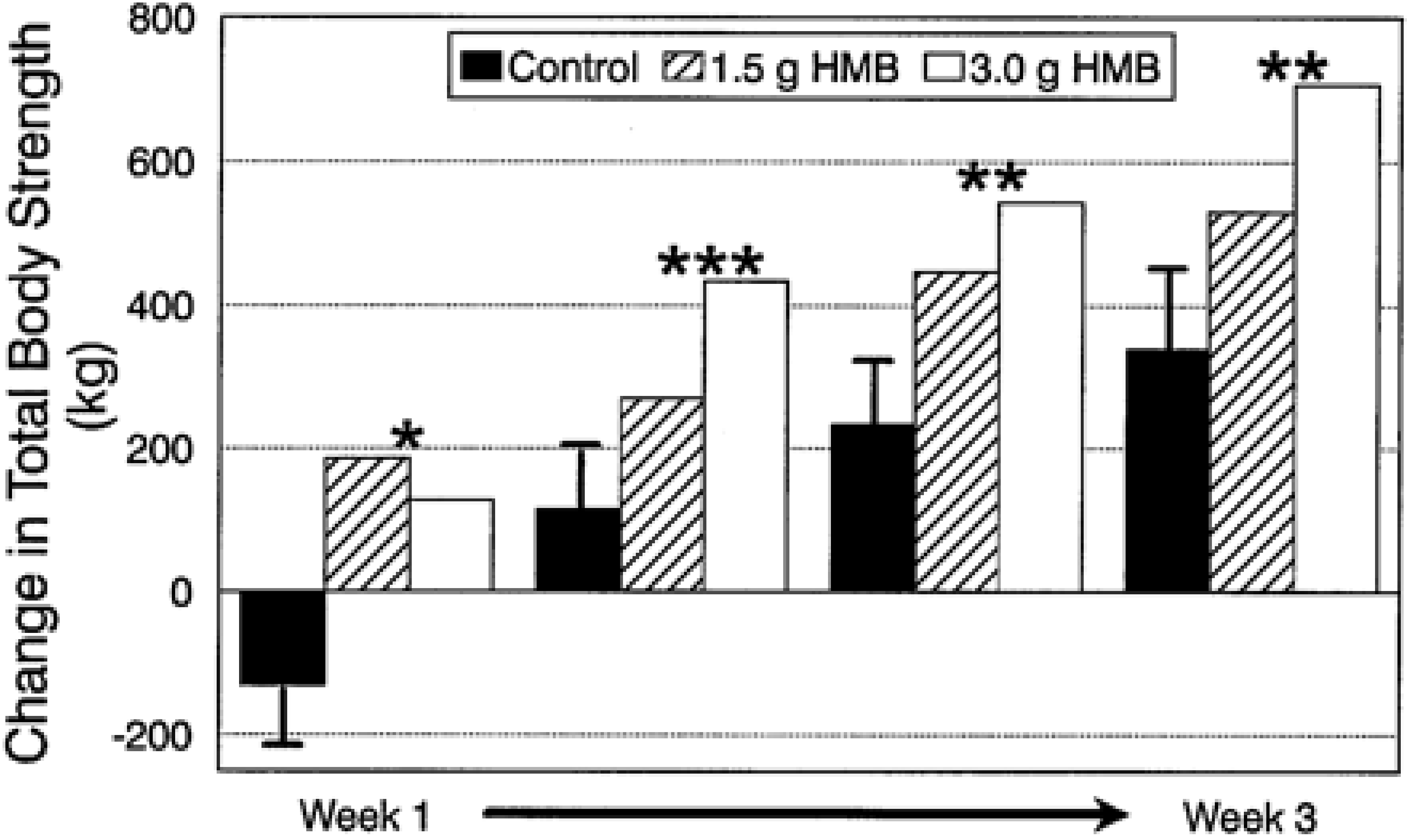
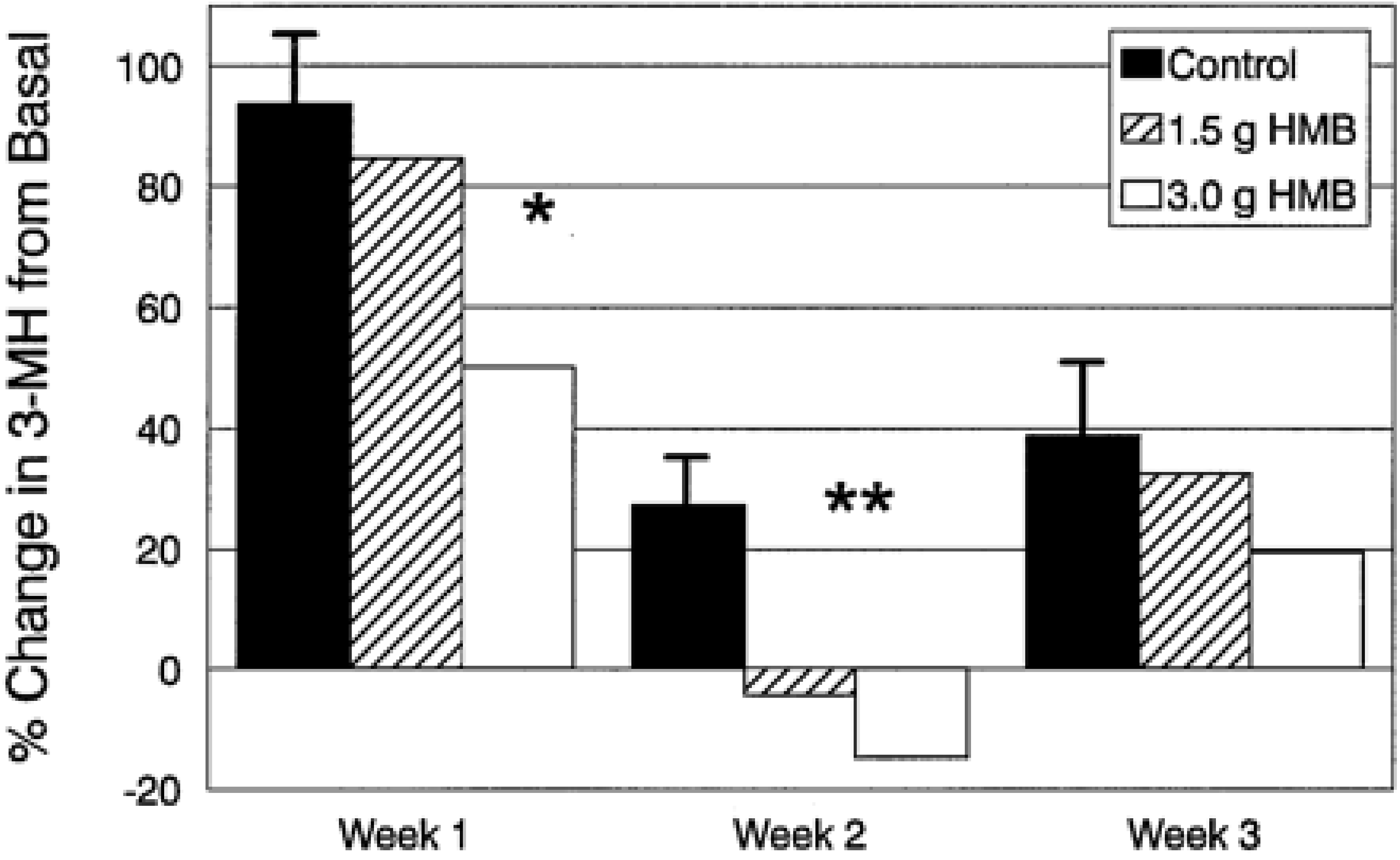
Beta Alanine



Nissen et al, J Appl Physiol 81:2095-2104, 1996



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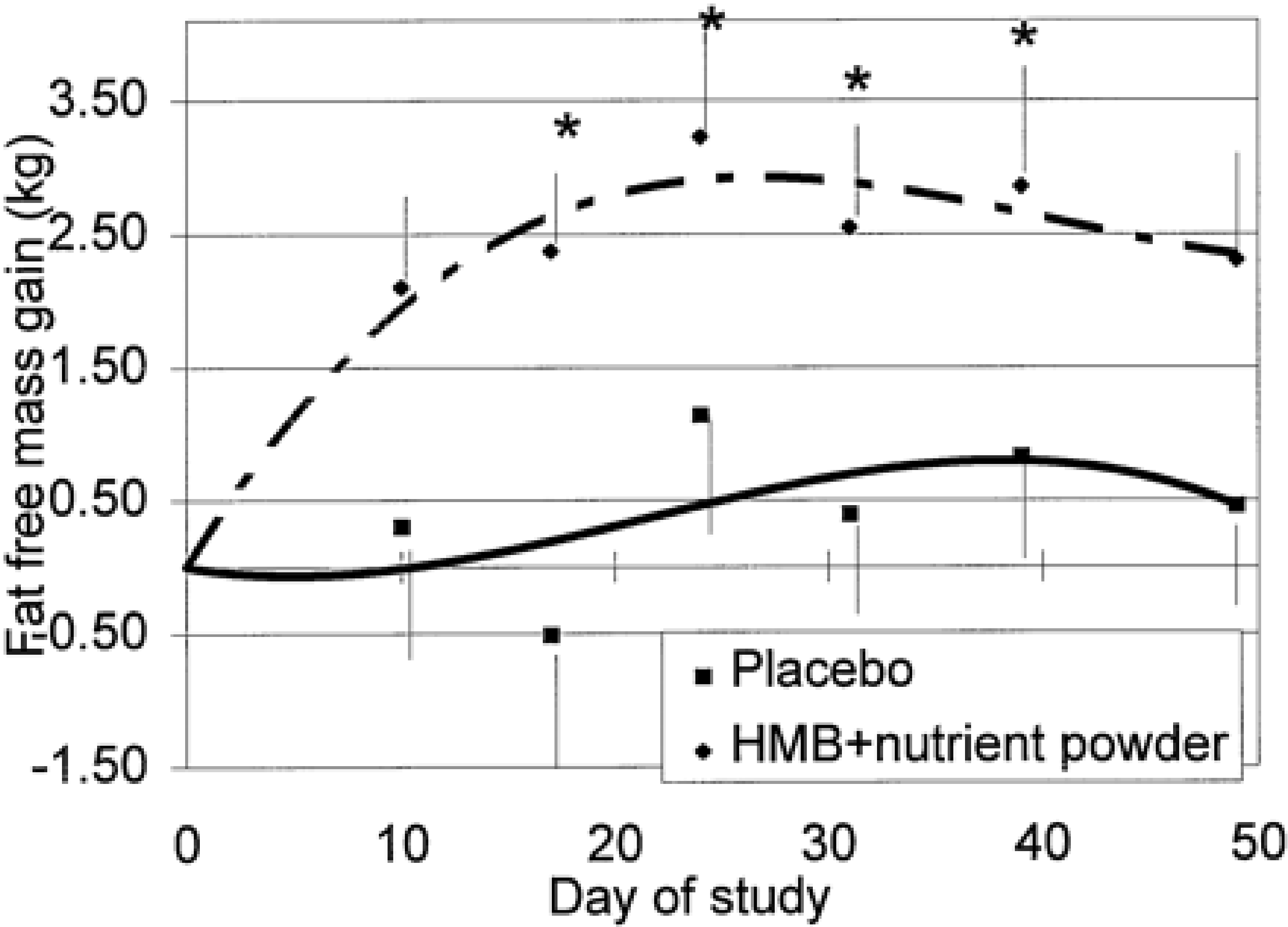

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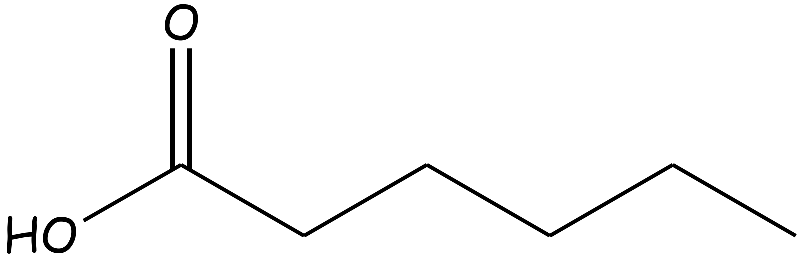
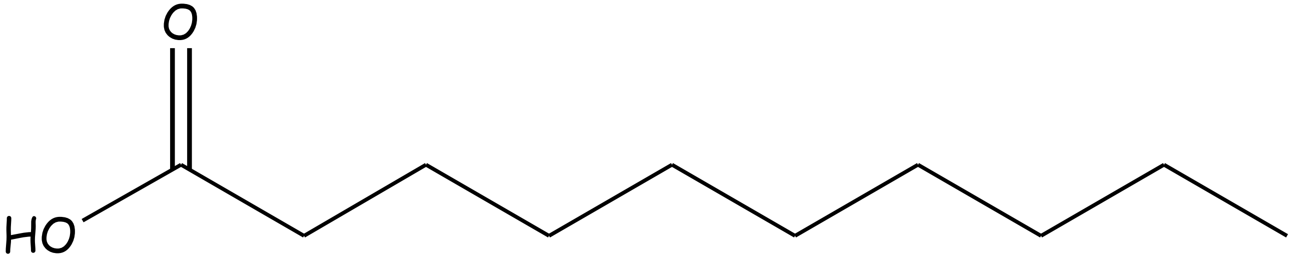
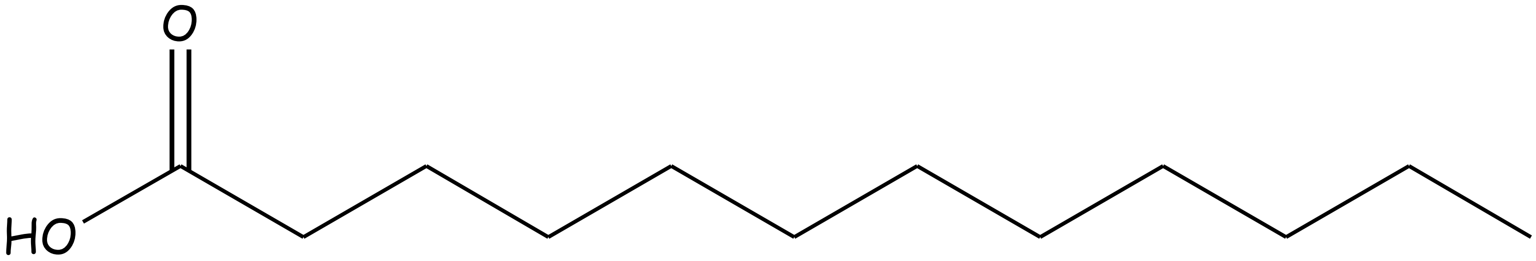


caproic acid



capric acid



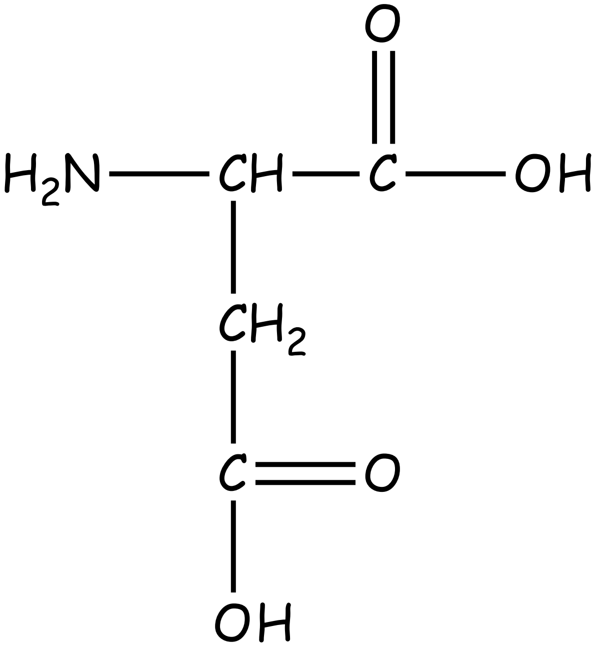
lauric acid

Medium Chain Triglycerides

- contain MCFA which do not require carnitine transport system
- MCFA are used for energy during exercise
- does not enhance performance

Research

- MCT did not improve 100-km TT versus carbohydrate (Angus et al, J Appl Physiol 88(1):113-9,2000)
- MCT did not improve performance in 2 hour cycling bout at 63% VO2max followed by a 40-km TT (Horowitz et al, J Appl Physiol 88(1):219-25,2000)
- potential for diarrhea and GI discomfort exist (Jeukendrup et al, AJCN 67(3):397-404, 1998)



aspartic acid

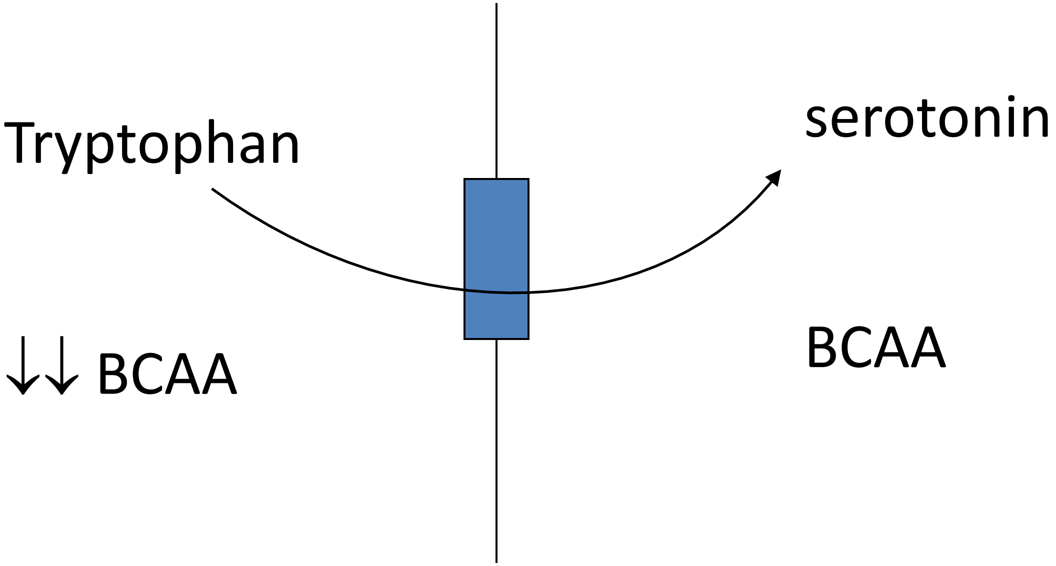
Purported Mechanism(s)

- involvement in urea formation
- glycogen sparing as Carbon skeleton is OAA

- 6 g of Asp for 24-hours did not improve cycling performance or ammonia levels (Maughan and Sadler, Int J Sport Med 4:119-23, 1983)
- 24-h of Asp did not effect NH_4+ levels during/after resistance training (Tuttle et al, Int J Sport Nutr 5(2):102-9 1995)
- 15 g of Asp/Arg for 14 days failed to change RER, FFA, lactate or ammonia during and after marathon (Colombani et al Eur J Nutr 38(6):263-70, 1999)

Purported to reduce Central Fatigue in endurance sports and possibly be immunoprotective

- serotonin effect
- decreases the reduction of glutamine typically observed in endurance sports



Tryptophan

serotonin

↓↓ BCAA

BCAA